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Generation and Attenuation of Leachate from Fluidized-Bed Combustion Solid Wastes: First Year Progress Report

Radian Corp.
Austin, TX

Prepared for

Industrial Environmental Research Lab.
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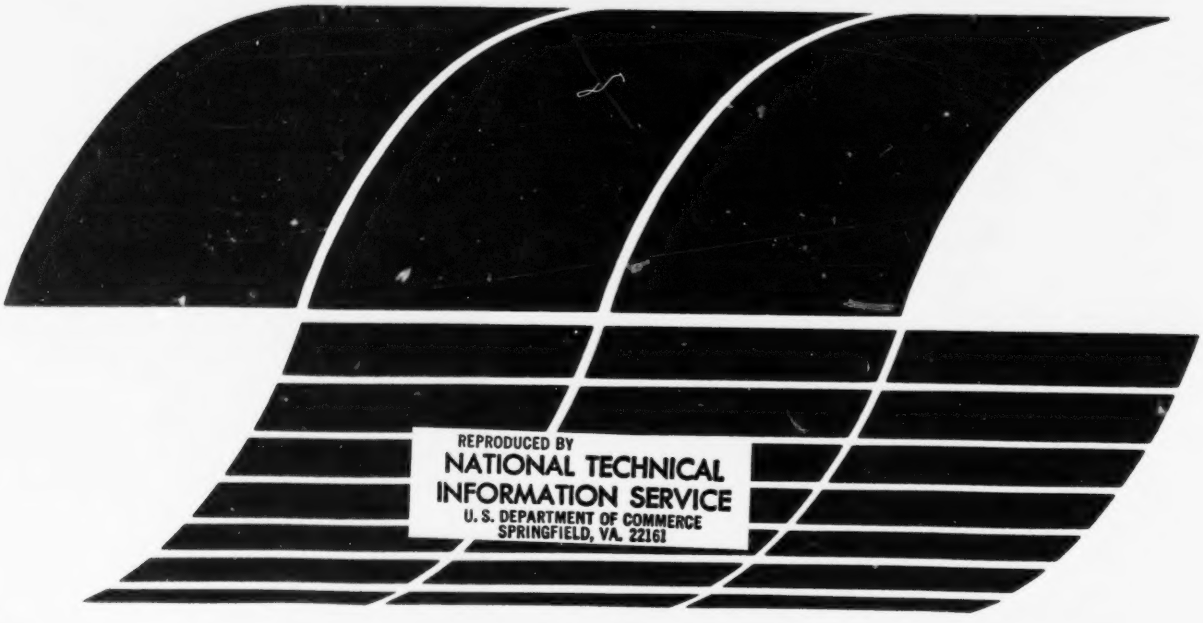

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ABSTRACT

Fluidized bed combustion (FBC) residues may pose hazards to the environment unless they are properly disposed of. This study addresses these concerns in two ways: 1) analysis of representative FBC residues and their interaction with natural environmental media; and 2) development of a methodology for ensuring environmental protection from the impacts of FBC wastes on a case-by-case basis. During the first year, the residues from pressurized FBC and their interaction with six representative disposal media (sandstone, shale, alluvium, glacial till, limestone, and interburden) have been studied. The investigations include a multistep laboratory protocol for leachate generation from FBC wastes and subsequent attenuation of the leachate by the disposal media. Field studies utilize seventeen large (four-foot diameter, seven-foot long) cylindrical cells containing combinations of FBC waste and disposal media types. Detailed results of laboratory and field studies of leachate generation and attenuation are presented for three example parameters -- calcium, boron, and sulphate. More cursory examination of these parameters and 17 others was conducted by comparing volume-weighted averages of leachate concentrations with primary and secondary drinking water standards, Multimedia Environmental Goals (MEGS), and Quality Criteria for Water (QCW). With respect to drinking water standards, the parameters of greatest concern are cadmium, manganese, sulfate, and total dissolved solids. For the MEGS, calcium, cadmium, cobalt, nickel, potassium, silver, and manganese are all of concern. Only boron is considered of special concern with respect to QCW.

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EXECUTIVE SUMMARY

Fluidized bed combustion is an emerging energy conversion technology that holds promise for high efficiency of energy conversion, but the solid residues generated during the process may pose hazards to the environment unless they are properly handled and disposed of. The purpose of this investigation is to address the environmental concerns of FBC waste disposal in two ways: 1) analysis of the characteristics of representative FBC residues and their interaction with natural environmental media; and 2) development of a methodology or conceptual model for use in planning environmental protection from the impacts of FBC wastes on a case-by-case basis.

The investigation reported here has several components: 1) identification and acquisition of representative FBC solid residues and natural disposal media (geologic materials); 2) characterization of several physical properties of the FBC residues and disposal media; 3) laboratory studies of leachate generation from FBC residues and subsequent leachate attenuation by the disposal media; 4) lab studies of interactions between landfill liners and FBC residues; 5) construction and operation (leachate collection and analysis) of simulated landfill cells that are in natural field conditions but in hydrologic isolation from the environment; 6) development of methods of "scaling up" from laboratory batch equilibration tests to leachate generation and attenuation phenomena observed in field cells; and 7) application of the "scaling up" methods to formulation of a conceptual model for case-by-case dispoal site application. Studies during the first year have included pressurized FBC (PFBC) wastes and six disposal media (sandstone, shale, alluvium, glacial till, limestone, and interburden).

Physical characterization of the FBC waste and the disposal media have included X-ray diffraction analysis, particle size, specific surface area, and specific gravity determinations, and scanning electron microscope and electron microprobe analysis. Chemical analyses have been performed on PFBC leachates both before and after exposure to the disposal media. Analyses are made for 20 water quality parameters. Detailed results of the chemical behavior of leachates during the generation and attenuation phase in both laboratory and field studies are presented for the parameters calcium, boron, and sulfate. When the wastes are leached repeatedly with fresh water in laboratory studies, the leachate concentrations of calcium and boron decrease markedly. Sulfate concentrations remain relatively constant with increasing leaching. In laboratory studies of the attenuation of fresh leachate by the disposal media, calcium is attenuated by all of the media, although attenuation trends vary for the different media. Boron is strongly attenuated by all of the media, and sulfate is attenuated very little by any of the media.

Leachates collected from sampling points just below the waste body in the field cells (leachate generation phase) generally decrease in strength with respect to calcium, boron, and sulfate as increments of water flow through the cell and leaching progresses. Leachates from sampling points below the disposal media in the cells (leachate attenuation phase) are less consistent. The prevalent pattern of calcium, boron, and sulfate concentration is to remain constant or to gradually increase with time and leachate volume flow-through.

The concentrations of all 20 analytical parameters have been tabulated for the leachate generation and attenuation phases of both laboratory and field studies. In this presentation, a comparison of the leachate strength is made for all 20 parameters with existing primary and secondary drinking water standards, Multimedia Environmental Goals, and Quality Criteria for Water. With respect to drinking water standards, the parameters of greatest concern are cadmium, manganese, sulfate, and total dissolved solids. For the Multimedia Environmental Goals, calcium, cadmium, cobalt, nickel, potassium, silver, and manganese are all of concern. Only boron is considered of potential concern with respect to Quality Criteria for Water.

Future program efforts include the acquisition of atmospheric FBC (AFBC) wastes from two sources, laboratory leachate characterization studies for the AFBC wastes, investigation of the effect of FBC wastes on landfill liners, and completion of the field cell test matrix with the new wastes. Further statistical refinements of the attempted "scaling up" from laboratory to field observations of leachate generation and attenuation will be made, and the results will be incorporated into the development of the conceptual methodology for ensuring environmental protection of future individual FBC waste disposal sites.

SECTION 1

INTRODUCTION

Fluidized bed combustion (FBC) is an emerging energy conversion technology that holds promise for high efficiency of energy conversion as well as minimization of adverse impacts on air quality. In a fluidized bed combustor, the fuel (usually coal), is mixed with a sorbent material (limestone or dolomite), and the mixture is held in entrainment suspension in the combustor by air that is forced at high velocity through an air distribution grid at the bottom of the combustor.

A major advantage of FBC lies in the fact that high-sulfur coal can be burned without the use of flue-gas desulfurization equipment to meet air quality standards. As the coal is burned in the combustor, the sulfur present is oxidized to sulfur oxides as in conventional boilers. However, the sulfur oxides react with the sorbent material in the fluidized bed to form calcium sulfate instead of being carried out to the atmosphere in the flue gas. Although FBC has the strong environmental advantage of cleaner flue gas with respect to sulfur oxides, the additional solid residues generated as a result of the sorbent material, coupled with their different properties from conventional combustion by-products, could potentially represent an increased environmental hazard from solid waste disposal.

The EPA Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina, has initiated a comprehensive effort for characterizing FBC residues and emissions and their potential environmental effects. The use of this "front-end" approach for an emerging, highly promising energy conversion technology enables planning and engineering to deal with environmental problems before large facilities are in existence.

The investigation reported here is a major part of the IERL-RTP environmental characterization efforts for FBC. This study, a three-year program being performed under Contract 68-02-3103, has as its major objective the evaluation of the environmental acceptability of solid residues generated by FBC. This report presents the progress and findings of the first year of the program.*

OBJECTIVES

The objectives of this study are to ascertain the degree of potential environmental hazard posed by FBC solid residues and to provide a means of ensuring environmental protection when the residues are disposed of. Specifically, the program has been structured to:

- analyze the characteristics of representative FBC residues and their interaction with natural environmental media; and
- develop a methodology or conceptual model for use in providing environmental protection from the impacts of the residues on a case-by-case basis.

An environmental assessment of FBC solid wastes should take into account all facets of the environment as well as the costs associated with environmental protection. Components of the natural environment which are usually considered include climate, air quality, noise, odor, topography, soils, geology, hydrology (including both surface water and ground water), and biology (including both terrestrial and aquatic ecology). In addition to these natural components, several anthropogenic categories normally are also considered, including socioeconomics, land use, and cultural resources (both archaeologic and historic categories).

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*Because of delays in the availability of FBC wastes, the preparation of the first year progress report was delayed for three months. This report therefore presents the results of the first fifteen months of investigation.

However, the primary focus of concern for the environmental acceptability of FBC waste disposal is on the potential hydrologic impacts. There are two reasons for this emphasis. First, the hydrologic systems are the environmental components that are most likely to be adversely affected and that are regulated by pollution control efforts. Second, the other major environmental components, when affected by solid waste disposal sites and operations, are often affected by means of contaminated ground or surface water. Thus, the other components are affected adversely only if or after the hydrologic components are affected.

For example, the potential adverse effects of FBC wastes on both terrestrial and aquatic systems are reflected through hydrologic systems. Aquatic habitats in streams would most likely be affected as a result of inflow of contaminated surface water or ground water into the streams. Terrestrial plants downgradient from the disposal site could be affected by contaminated ground water if the plants are taking water from below the water table. Wildlife could be impacted by taking water from streams that are contaminated by surface runoff from the disposal site or by inflowing ground water.

Many of the cultural concerns of solid waste disposal also occur via hydrologic systems that have been contaminated by the disposal site. Where water supplies are taken from ground water directly, the contamination of ground water represents an easily identifiable threat. The acceptability of a disposal site to an informed public is directly related to the threat of the site to the local commodities of value, including water supply sources. The regulatory climate in a state, county, or community will bear on the disposal practices used at a site and will determine in large measure the relative degree of hydrologic impact of the disposal site.

Because of the potential direct impact of FBC solid waste disposal on surface water and ground water, and because the impacts on other environmental components of greatest value occur via hydrologic systems, the emphasis of this study is placed on the potential hydrologic impacts. This is not to say that the impacts on other environmental components should be ignored, but the initial emphasis should be placed on the more important hydrologic impacts.

SCENARIO DISPOSAL CONDITIONS

FBC solid residues have potential for use as concrete additives and as aggregate in asphalt and concrete, and some residues may be disposed in the ocean.[1] However, the bulk of future FBC wastes will likely be disposed in landfills. This investigation is being conducted with an emphasis on the potential environmental problems associated with landfill disposal.

There are as yet no viable commercial FBC plants in operation, and consequently, there are no representative disposal operations to serve as a guide for this investigation. In order to provide bounds for the study, a set of "typical" future disposal operating conditions will therefore be assumed. These scenario conditions are based on landfill operation for other types of solid wastes.

As the solid residuals are generated in the combustors, they will be brought to ambient temperature before temporary storage at the plant site. From temporary storage the wastes will be pneumatically loaded at appropriate intervals into closed tractor-trailer type trucks and will be hauled to the treatment/disposal site. It will be assumed that the disposal site will be sufficiently close to the plant to allow transportation by truck. At the disposal site, the wastes will be removed from the trucks and again placed in temporary storage (e.g., silos). From this temporary storage the wastes will be transferred to a waste treatment facility where water will be added in the proper stoichiometric amounts such that hydration reactions and subsequent heat release can occur under controlled conditions. If stabilizing additives are required for the waste, they will also be added during this step.

The primary purpose of the treatment step is to prepare the wastes so they can be safely disposed in a hydrated and thermally stable form. It is assumed that after treatment the wastes will still be in a solid form suitable for landfill disposal. Pond disposal is assumed to be unnecessary and, in fact, undesirable.

It is further assumed that the disposal site will be devoted solely to FBC wastes. Codisposal with other types of wastes will not be considered in this program, although codisposal with certain other wastes may present distinct advantages, much as the mixing and codisposal of ash from conventional coal-fired boilers with sludge from flue gas desulfurization equipment increases the stability of these wastes. Codisposal is a potentially fruitful area of future FBC waste investigations.

After treatment, the FBC wastes will be transported to the landfill for final emplacement. A primary requisite for a satisfactory disposal site is that the water table will at all times be below the base of the waste. Generally, at least five feet of unsaturated substrate should underlie the wastes to aid in attenuation of contaminants and to reduce the leaching of the wastes. The release of contaminants from the wastes is generally much greater if the wastes are below the water table and remain saturated than if they are in the unsaturated zone where they are leached only periodically by infiltrating precipitation. The scenario disposal site assumed here has at least five feet between the base of the landfill and the highest level of the water table. Such an assumption is also congruent with evolving regulations for waste management in EPA's Office of Solid Waste.

If an FBC waste disposal site is operated as a traditional landfill, then its geometry can reasonably be postulated. For a trench method, there will be tabular bodies, 10 or so feet thick, 20 or so feet wide, and perhaps a few hundred feet long, spaced on, say, 50 foot centers. For an area method there will be a large number of small cells, say 10 x 20 x 20 feet, separated by 2 to 3 foot earth walls making up a large tabular body 10 feet thick and a few hundred feet wide and long. Two or more such bodies might be superposed. While actual landfill sites are fit into the existing topography, it is reasonable to proceed with this general concept of site geometry.

For such a hypothetical disposal site, a typical section would consist of the following layers or components:

- final cover material consisting of two or more feet of soil for the site vegetation;

- upper liner (optional), which is a moisture barrier about the waste body; it may be natural material (such as clay) or artificial (flexible membrane of some sort);

- waste body;

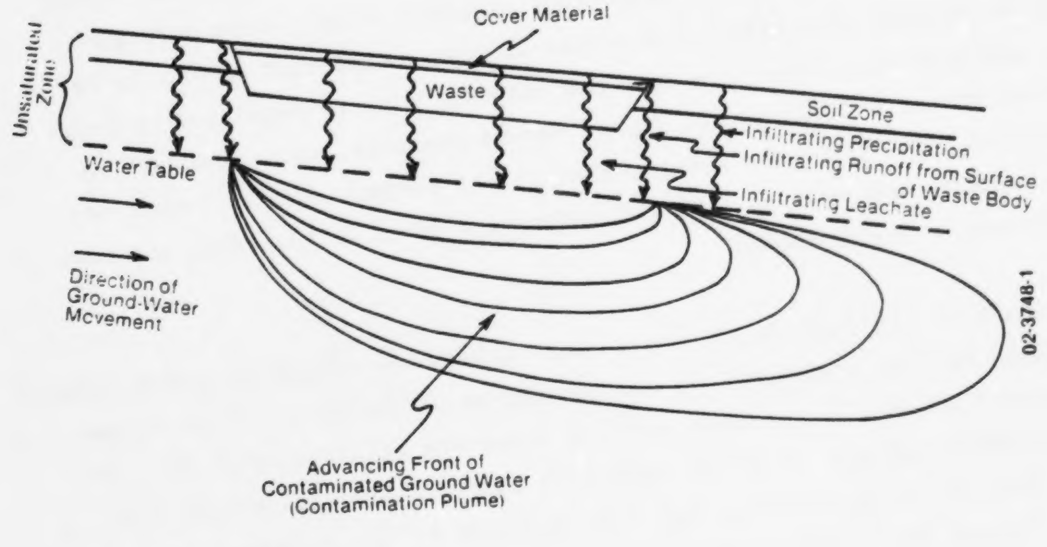
- bottom liner (optional), which is a natural or artificial barrier to downward moisture (leachate) movement, and may incorporate a fluid collection system;

- unsaturated disposal media, undisturbed site material lying below the landfill, but above any regional ground-water system; and

- saturated zone of the ground-water system.

With respect to disposal environment, a uniformly sloping surface of low slope angle is hypothesized. A homogeneous and isotropic substrate medium (such as a well-sorted non-stratified sand) is assumed, and a water table aquifer is presumed to be present. The slope of the water table is assumed to be the same as the slope of the land surface. The ground-water contamination plume that would likely be generated under these circumstances is shown in Figure 1.

Although these idealized disposal conditions would seldom be realized in actual disposal sites, the scenario provides a means of developing a methodology for addressing disposal problems at individual sites. The methodology can then be modified as necessary to fit the more complex "real" conditions at the individual sites.


Cover Material
Unsaturated Zone
Waste
Soil Zone
Infiltrating Precipitation
Infiltrating Runoff from Surface of Waste Body
Infiltrating Leachate
Water Table
Direction of Ground-Water Movement
Advancing Front of Contaminated Ground Water (Contamination Plume)
02-3748-1

Assumption: Homogenous. Isotropic Substrate

Figure 1. Scenario Landfill Disposal Site

ENVIRONMENTAL REGULATORY CONTEXT

Recent national legislation and pursuant regulations concerning solid waste disposal will have a large impact on future waste disposal practices.[2] Of particular significance are the Resource Conservation and Recovery Act of 1976 (PL 94-580) and regulations that are being developed by EPA in response to the act. The regulations, which are presently being developed or have only recently been promulgated, provide for a means of making a distinction between hazardous and nonhazardous wastes. Hazardous wastes are controlled from the point of origin to the point of final disposal by means of a manifest system and by requirement of isolated, leak-proof disposal sites. Less stringent control is imposed on nonhazardous wastes in that no manifest system is required, and leakage of leachate from the disposal site is permitted as long as no underground drinking water source beyond the solid waste boundary is contaminated. The FBC waste program that is the subject of this report addresses both the eventuality that FBC waste is classed as hazardous and that it is classed as nonhazardous.

Inasmuch as the bulk of FBC wastes will likely be classed as nonhazardous,[2] the emphasis of this program is on the generation of leachate and the subsequent interaction of the leachate with the substrate at disposal sites. However, studies of the effect of FBC wastes on landfill liner materials that could be used to prevent leakage are also included in the program to account for those future FBC wastes that are classed as hazardous.

OVERVIEW OF PROGRAM CONTENT

In order to achieve the two-fold objective of characterizing FBC wastes and their interaction with the natural environment and developing a methodology for ensuring environmental protection on a case-by-case basis, the following specific elements have been established for the program:

- development and maintenance of a comprehensive literature file,

- identification and acquisition of representative FBC solid residues,
- identification and acquisition of representative "disposal media" (geologic materials from likely landfill environments),
- characterization of several physical properties of the FBC residues and disposal media,
- laboratory studies of leachate generation from FBC solid residues by means of batch equilibration tests,
- laboratory studies of leachate attenuation by disposal media,
- laboratory studies of interactions between landfill liners and FBC solid residues,
- construction of simulated landfill cells that are in natural field conditions but that are hydrologically isolated from the environment,
- collection and chemical analysis of leachate samples from the field cells at two points located so as to enable analysis of leachate from waste material both before and after exposure to the disposal medium,
- development of methods for "scaling up" from laboratory batch equilibration tests to leachate generation and attenuation phenomena desired in field cells; and
- application of the "scaling up" methods to formulation of a conceptual model for case-by-case application.

A number of program tasks have been established to accomplish these elements. An information services task provides the means of acquiring relevant publications and unpublished materials from previous studies. A task for waste acquisition is included to identify possible sources of representative FBC wastes and to acquire sufficient quantities of the waste for laboratory and field studies. This task is also charged with the responsibility of defining FBC operational parameters that existed when the waste acquired was produced.

Characterization of FBC Wastes and Representative Disposal Media

A laboratory studies task was established to conduct lab investigations of the physical and chemical properties of both the representative FBC wastes selected and the candidate disposal media that are also selected as representative materials. A major part of the lab studies effort is in the batch equilibration tests that are used to simulate the generation of leachates from waste samples. These "shake" tests are also used to study the attenuation of leachate contaminants by various candidate disposal media. Other laboratory studies are the whole-sample chemical characterization of wastes, examination of crystalline phases present, and studies of the effects of FBC waste leachate on several candidate landfill liner materials. All laboratory studies are being conducted at Radian Corporation laboratories in Austin, Texas.

The field studies task includes installation and operation of several large cylindrical field cells to simulate the behavior of actual landfill cells under quasi-natural conditions. The identification and acquisition of suitable representative disposal media also fall under the purview of the field studies task. Laboratory control columns to investigate the leaching of disposal media in the absence of FBC waste are also included in this task. These control columns are smaller in length and diameter than the field cells. All of the field cells are located at an EPA field laboratory at Crown, West Virginia (near Morgantown), but the control columns are in laboratory facilities in Austin.

A task was also set up in the program for chemical analysis of all leachates produced in the laboratory and field cells. Most analyses are done by ICPES (Inductively Coupled Argon Plasma Emission Spectroscopy), although some analyses are performed by AAS (Atomic Absorption Spectroscopy), specific ion electrode, and ion chromatography. A separate task for data handling and analysis was established to enable the use of digital computers and the SAS (Statistical Analysis System) capability to process and display the analytical results of the chemical analysis task. A quality assurance task was set up to ensure the accuracy and reproducibility of all chemical and physical determinations made in all tasks of the program.

During the first year of the program, studies have been completed for PFBC wastes from the Exxon Miniplant, Linden, New Jersey. The chemistry data from laboratory and field studies using these wastes are presented in Appendix I.

Development of Methodology for Providing Environmental Protection on a Case-by-Case Basis

The variability of the environmental conditions at future disposal sites, coupled with the variability of the characteristics of future wastes, preclude the possibility of anticipating all environmental problems at all locations. A major goal of this investigation is therefore to develop a methodology or conceptual model for dealing with the environmental problems of FBC wastes on a case-by-case basis. When this methodology is developed, it is envisioned that selected site-specific and waste-specific parameters can be determined and used as input to the method to predict the probable hydrologic impacts of alternate waste disposal practices. In this way, a "best choice" of waste disposal method can be made.

A major objective of this program is an attempt to establish, by means of an empirical but rigorous correlation, a relationship between the results of laboratory shake tests and the leaching behavior of FBC wastes in the field. If this relationship can be established, then the leachate generation potential of future FBC wastes can be predicted on the basis of relatively inexpensive, easy-to-perform laboratory batch equilibrium tests. Such a leachate generation predictive tool will be incorporated as an essential part of the methodology for dealing with site-specific environmental problems.

It is expected that the results of this program and the results of other solid waste and ground-water contamination studies will be used to formulate the conceptual model that can be used to predict the hydrologic effects of individual solid waste disposal sites on a case-by-case basis. The conceptual model will likely be formulated, at least initially, to be applied to the "idealized" set of disposal practices and hydrogeologic conditions set forth in Figure 1.

Initial progress has been made toward achieving the empirical but reliable and rigorous correlation that is being sought between laboratory studies and field cell results. However, much work remains to be done before the correlation is demonstrated. As a result, the bulk of the efforts in developing the remainder of the conceptual model for case-by-case application remains to be done, although most of the applicable studies being conducted for other types of wastes have been identified and the appropriate reports and publications secured.

REPORT ORGANIZATION

Following this introductory section, Section 2 presents more details on the specific methods used to accomplish the program elements. Section 3 contains the results of studies performed thus far on the physical characteristics of FBC wastes and disposal media. Section 4 presents the results of the laboratory and field studies with an emphasis on comparison of leachates and their interaction with the disposal media. Current progress in development of the correlation of the results of laboratory and field results is also presented in Section 4.

Section 5 contains a comparison of the analytical results of raw and attenuated leachates from both laboratory and field efforts with several water quality standards, regulations, and criteria. The purpose of this section is to provide a framework for establishing the relative acceptability of FBC solid residues from an environmental quality standpoint. Section 6 presents a synopsis of work remaining to be accomplished during the remainder of the program.

SECTION 2

METHODS OF INVESTIGATION

As noted in Section 1, several technical tasks have been established to accomplish the objectives of this program. These tasks are as follows:

- Information Services,
- FBC Waste Identification and Acquisition,
- Field Studies,
- Laboratory Studies,
- Chemical Analysis,
- Data Management and Interpretation, and
- Conceptual Model Development.

The overall procedures used in each of these tasks are described in this section. Where required, specific procedural details are given in Appendix II.

INFORMATION SERVICES

The primary purpose of the information services task is to create an abstract file of FBC literature, retrieve relevant material, and maintain a separate FBC hard copy file. The initial literature search was done in September, 1978, and information is added to the file regularly. The on-line data bases that were searched are shown in Table 1. Literature published prior to 1969 was not searched inasmuch as FBC technology was virtually nonexistent at that time.

In scanning the print-outs, abstracts which indicated major emphasis on coal gasification were deleted, as were abstracts which discussed FBC as a future energy technology. About 1,500 of the 4,000 abstracts obtained were used to create the initial file. Additions to the abstract file are made as

TABLE 1. ON-LINE LITERATURE FILES SEARCHED FOR FBC CITATIONS

- APTIC (Air Pollution Technical Information Center), 1966-September, 1978.
- Biological Abstracts, 1969-
- Chemical Abstract, 1971-
- ENERGYLINE, 1971-
- Energy Data Base (DOE), 1976-
- Engineering Index, 1970-
- ENVIROLINE, 1971-
- Environmental Periodicals Bibliography, 1974-
- GEOARCHIVE, 1974-
- GEOREF, 1967-
- GRANTS, current
- Meteorology/Geophysics, 1970-
- National Technical Information Service (NTIS), 1964-
- Nuclear Science Abstacts (OCR/AEC), 1967-1976
- POLLUTION, 1970-
- Selected Water Resources Abstracts, 1968-
- SSIE, 1974-

new documents are purchased or abstracts or titles of current relevant literature are identified. Since October 1978, about 175 new titles have been added. About four titles are added monthly.

Two methods are used to update the files. New documents entering the file are given subject descriptors. Abstracts of new document titles which have FBC descriptors are culled, photocopied, and given new descriptors applicable to the specialized FBC file.

The second method is a current awareness service provided by the library through Lockheed Retrieval Service's DIALOG.® Abstracts added to the Engineering Index and Chemical Abstracts data bases discussing FBC and its environmental consequences are sent to the library on a regular basis. A separate search on DOE's Energy Data Base is made about every other month. The NTIS data base had been used for current awareness, but was dropped due to retrieval of irrelevant information.

All the abstracts obtained are circulated to individuals in the FBC program team for their perusal. Documents can also be ordered at the specific request of individual team members.

FBC SOLID RESIDUE IDENTIFICATION AND ACQUISITION

The first objective of this task is to identify current sources of FBC solid residues that are as representative as possible of wastes that will be generated when FBC becomes a viable and widely used energy conversion technology. The second objective is to acquire adequate samples of the residues for the laboratory and field portions of the program.

It is presently anticipated that three different FBC wastes will be tested; a pressurized FBC (PFBC) waste has been acquired and two atmospheric-pressure FBC (AFBC) wastes are to be obtained. Approximately ten tons of each FBC waste type are necessary to conduct the experimental work. The wastes used in the program are collected and transported to Crown, West Virginia and Austin, Texas.

Waste Requirements and Specifications

Waste is required for field cells, field permeameters, and the laboratory studies. The volumes of wastes needed are dictated by the field experiments, inasmuch as the laboratory studies require only small quantities. Each field cell has a four-foot inside diameter and contains a 1½ foot lift of waste. The field permeameters are the same diameter, but the solid waste layer is 2½ feet thick. The PFBC waste cells are in place and operating, and the laboratory studies have been completed on this waste. The AFBC wastes have not yet been obtained.

Every effort is being made to assure that the wastes tested in this program are representative of wastes anticipated from commercial FBC Facilities. The test units generating the waste are to be operating at steady state (meeting present environmental specifications for SO_2, NO_x, and particulates) and operating at a reasonable combustion efficiency. It is assumed that all the solid waste streams from an FBC facility are disposed of together, and that no other material is combined for co-disposal.

Figure 2 shows schematically three different AFBC processing configurations. Either solids recycle or two-stage operation with a carbon burnup cell (CBC) is anticipated to be required on a commercial installation because of the insufficient gas/solids contacting that occurs in a single stage FBC with reasonable operating parameters.

Originally, two AFBC wastes were to be tested that were generated with two different processing modes: recycle and carbon burnup cell (CBC). It appears now that AFBC-with-CBC waste will not be available within a reasonable time frame for this program. This circumstance precludes a comparison between AFBC-with-recycle and AFBC-with-CBC, but two different AFBC-with-recycle mode wastes appear to be available. Valuable information can be obtained from testing these two wastes, as they have significant processing and feedstock differences, and the overall program results do not depend on a single AFBC-with-CBC waste.

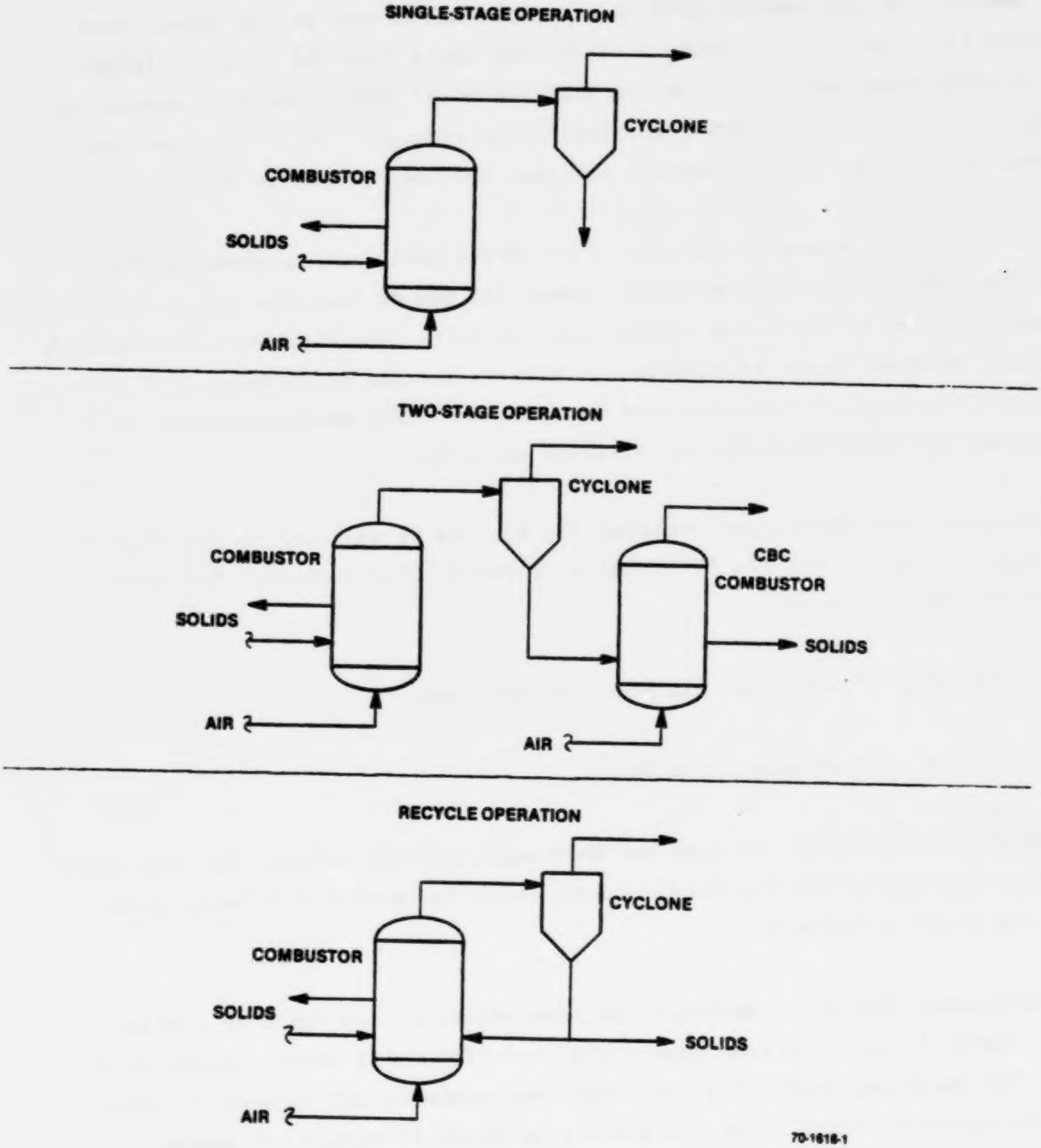

SINGLE-STAGE OPERATION
CYCLONE
COMBUSTOR
SOLIDS
AIR
TWO-STAGE OPERATION
CYCLONE
COMBUSTOR
CBC
COMBUSTOR
SOLIDS
SOLIDS
AIR
AIR
RECYCLE OPERATION
CYCLONE
COMBUSTOR
SOLIDS
SOLIDS
AIR
70-1618-1

Figure 2. FBC Operating Configurations

Wastes Received

Wastes from two sources have been secured and stored at the Crown, West Virginia field test site. These include PFBC waste from the Exxon Miniplant and "straight-run" material from the EPRI/B&W 6'x6' AFBC. The PFBC wastes are in operating field cells with a contingency in storage. The 6'x6' waste was secured at low cost for contingency only and has been placed in storage.

A simplified schematic diagram of the Exxon Miniplant is shown in Figure 3. After combustion, solid material leaves the bed as overflow and as elutriant. The bed overflow is one waste stream from the unit. The elutriant goes through the first cyclone, which is reported to have an overall efficiency of 95 percent, and the catch is recycled back into the bed. The material caught in the second and third cyclones is collected as waste.

Material from Exxon runs numbered 79, 80, and 81 was used in the laboratory protocol and in the six field cells presently in operation. The feedstocks for these runs were:

- Illinois #6 coal from the Monterey Mine, and

- Pfizer 1337 Dolomite from Ohio.

The solids feed size for the coal was 8x50 mesh, and the sorbent was 8x25 mesh. The operating conditions for the Miniplant while the wastes were being generated are given in Table 2.

Additional PFBC waste material has been obtained from Exxon as contingency. Table 3 lists the contingency AFBC and PFBC solid wastes presently on hand. The operating conditions for Exxon runs numbered 102 through 105 have not been obtained, but will be available from Exxon if wastes are needed. The AFBC waste is straight run material from the 6'x'6, and is therefore not totally representative of anticipated future wastes and will not be used unless other planned waste sources cannot deliver.

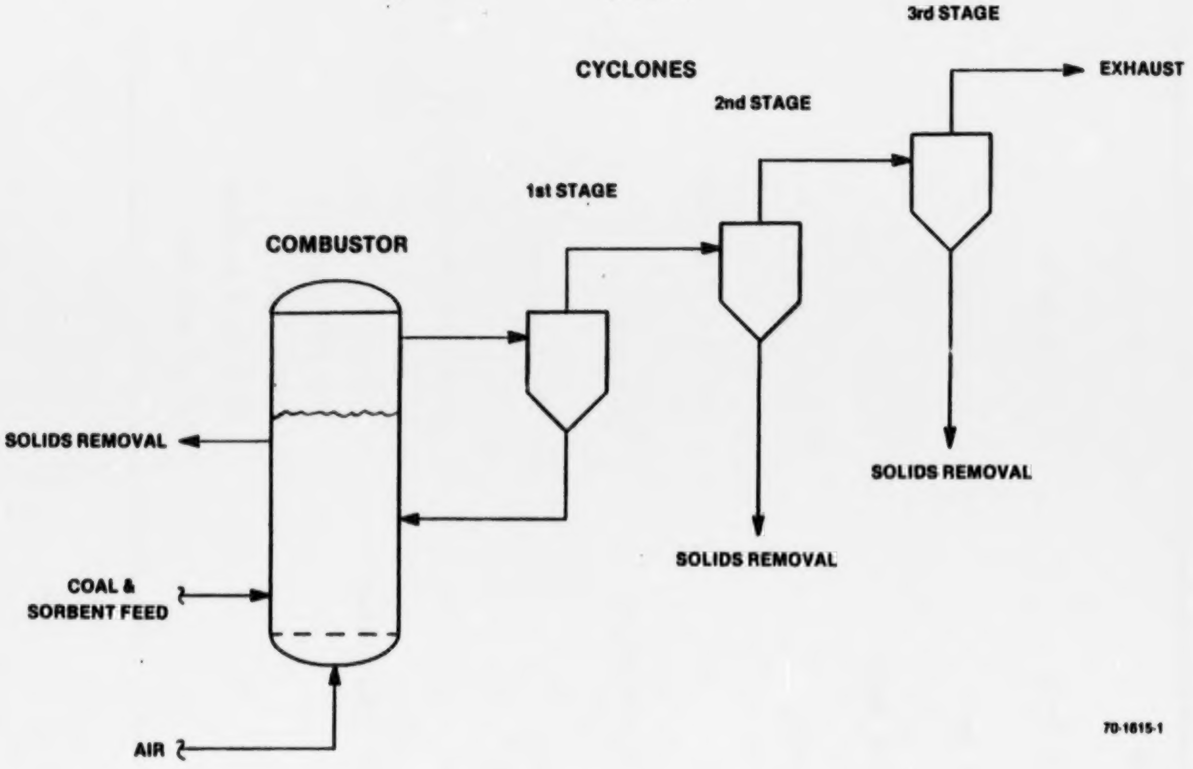

CYCLONES
3rd STAGE
2nd STAGE
1st STAGE
EXHAUST
COMBUSTOR
SOLIDS REMOVAL
SOLIDS REMOVAL
SOLIDS REMOVAL
SOLIDS REMOVAL
COAL &
SORBENT FEED
AIR
70-1615-1

Figure 3. Schematic of Exxon Miniplant PFBC

TABLE 2. AVERAGE OPERATING CONDITIONS FOR EXXON PFBC MINIPLANT RUNS NUMBERED 79, 80, AND 81

Bed Depth	2-4 meters
Coal Feed Rate	130 kg/hr
Air Feed Rate	21.4 m^3/min
Ca/S Molar Ratio	1.4
Temperature	925°C (1700°F)
Pressure	925 kpa (135 psi)
Superficial Velocity	1.8 m/sec
Excess Air	18-27 percent
S Removal	85-95 percent
Stack Gas Composition:	
SO_2	150-290 ppm
NO_x	56-120 ppm
CO_2	12.5-14.5 percent
O_2	3.5-5 percent

TABLE 3. CONTINGENCY FBC WASTE IN STORAGE AT CROWN, WEST VIRGINIA

Source	Stream	Run #	Volume (Drums)
Exxon Miniplant	2nd Cyclone	102	4
	2nd Cyclone	103	6
	2nd Cyclone	104	3
	3rd Cyclone	103	1
	3rd Cyclone	104	1
	3rd Cyclone	102 & 105	1
	Bed Overflow	104	1
	Final Bed Material	115	1
	Regenerator Cyclone Ash	102	1
	Regenerator Cyclone Ash	103	1
6'x6' AFBC	Spent Bed Material	--	10
	Cyclone Catch	--	36

AFBC Waste Availability

Because no commercial AFBC units are presently operating, it will be necessary to obtain the wastes for this program from existing AFBC test units. The operating AFBC test units can be categorized as government or privately sponsored. The test units that are sponsored by the Department of Energy and that have an inside diameter of over one foot are at the Morgantown Energy Technology Center; Grand Forks Energy Technology Center; MIT; Rivesville, West Virginia; and Alexandria, Virginia. The Georgetown University and Great Lakes Naval Station boilers are presently coming on-line. EPA has a test unit at Research Triangle Park and has contributed to an FBC unit at MIT. Privately funded units are operated by Babcock & Wilcox, Combustion Engineering, Foster Wheeler, Fluidyne, ERCO, Combustion Power, and Johnson Boilers.

AFBC-With-CBC Waste Availability--

The only facility in the country that can produce AFBC-with-CBC waste directly is the DOE-sponsored 30 megawatt (MWe) boiler located at Rivesville, West Virginia. Unfortunately, the future operation of the Rivesville boiler is uncertain, and consequently this boiler cannot be relied upon for waste acquisition for this program.

One other option for obtaining AFBC-with-CBC wastes would be to simulate the operation by obtaining the waste from a single-stage combustor and firing the elutriated material under CBC conditions as a separate step. Two important parameters for simulating CBC combustion are an operating temperature of about 2000°F and 20 to 30 percent excess air. This option was pursued to the point of obtaining "straight-run" material from the EPRI/B&W 6'x6' and receiving competitive bids for the simulated CBC operation, but it is not cost-effective to pursue this option further at this time. As noted, the straight-run wastes acquired are being stored for contingency use.

Government and private AFBC operators were contacted to assess the possibility of their simulating a CBC. The government installations all had defined test plans that did not include such operation, and considerable time and money would be required to retrofit the test units to allow 2000°F operation. Fixed-price bids were solicited and received to process the straight run material as required. The costs from the two bids were judged as too expensive for this program. Thus, AFBC-with-CBC wastes do not appear to be available for testing.

AFBC-With-Recycle Waste Availability--

Two sources of representative AFBC-with-recycle waste are to be operating within three months. The EPRI/B&W 6'x6' is presently being modified to allow a higher recycle rate and to include a baghouse for final particulate collection. Waste acquisition from the 6'x6' has been discussed with EPRI and B&W, and arrangements for acquiring this waste are presently being finalized.

A second source of AFBC-with-recycle waste is the Georgetown University AFBC boiler. Both DOE and Georgetown University officials have been contacted regarding the waste acquisition, and verbal approval has been obtained. The Georgetown University boiler has operated for short periods firing coal and is presently in the start-up phase.

LABORATORY STUDIES

Laboratory studies are being carried out to determine the following physical and chemical characteristics of pertinent components:

- physical and chemical properties of FBC wastes and disposal media,
- leachability of FBC wastes,
- attenuation/mobilization capacity of six disposal media, and
- compatability of candidate landfill liner materials with FBC wastes.

The leaching potential of FBC solid residues and the attenuation capacity of various disposal media are evaluated from the results of batch equilibration tests. These tests comprise extractions of the FBC wastes and disposal media with the appropriate solutions at a constant agitation rate. Major and minor chemical components in these extraction leachates are monitored to define trends in the chemical behavior during leachate generation and attenuation. This behavior has been monitored through a stepwise protocol designed to simulate primary and secondary effects in leaching and attenuation.

During the first year, physical characterization of the PFBC solid residues and the six disposal media was performed to identify pertinent structural properties and physical characteristics that will be utilized in the interpretation of leaching data. The principal methods used in the physical characterization investigation are X-ray diffraction, scanning electron microscopy, specific gravity analysis, and surface area analysis. The results of the physical characterization of the PFBC wastes and the six disposal media are presented in Section 3 of this report. The laboratory studies of PFBC waste leachates and their interaction with the disposal media are reported in Sections 4 and 5.

Chemical analysis of whole samples at each FBC waste and disposal medium included in the program will also be performed. It is expected that the samples will be acid-digested and analyzed for the chemical parameters included in the list described below for leachate analysis. These analyses will be performed when all FBC wastes and disposal media have been acquired.

Determination of Leachability of Wastes

In development of the procedures for the waste leachability studies, the literature was searched for tests already developed and in current use.[3,4,5,6] The results of the literature search and preliminary shake tests conducted on FBC wastes for this program were used to develop the procedures for the batch equilibration ("shake") tests and to determine the most significant variables. Variables that were considered in the development of the batch equilibration tests are (1) time of agitation and leaching, (2) solid-to-liquid ratio, (3) nature of leaching liquid phase (e.g., pH), and (4) method of agitation.

Based upon the results from the studies for this program and results from other leaching tests found in the literature, the following parameters were formulated and have been utilized thus far:

(1) the extracting liquid phase is deionized water;

(2) the extraction times are 1 day, 2 days, and 7 days;

(3) the solid-to-liquid mass ratio is 1:10 (25g:250 mℓ H_2O) in order to minimize common ion and solution nonideality effects for species of interest;

(4) all wastes and disposal media are ground to obtain uniform particle size to insure homogeneity of wastes and reproducibility;

(5) continuous solid and liquid agitation is maintained on a rotator at constant specified parameters to insure maximum contact with minimum particle abrasion. The Rugged Rotator, Model RD-250 (manufactured by Kraft Apparatus, Inc.) was selected because it permits good eluant-solid contact without such vigorous agitation as to cause abrasion of the solids (Figure 4).

The laboratory protocol consists of six related steps (Figure 5), three steps to characterize the behavior of one waste and three steps to characterize a disposal medium. The 2nd and 3rd steps for the waste and the 5th and 6th steps for the medium are repeated until minimal changes in leaching or attenuation are observed. Step 1 determines initial leaching (both rate and extent). Secondary leaching is determined in Steps 2 and 3 -- Step 2 with liquid replacement and Step 3 with solids replacement. The following sections describe each of these in more detail.

Step 1 -- Initial Leaching--

FBC waste is leached with deionized water to measure primary or initial leaching. The solid and liquid phases are equilibrated for one day, two

Figure 4. Rugged Rotator, RD-250 with Leachate Bottles in Position for Agitation

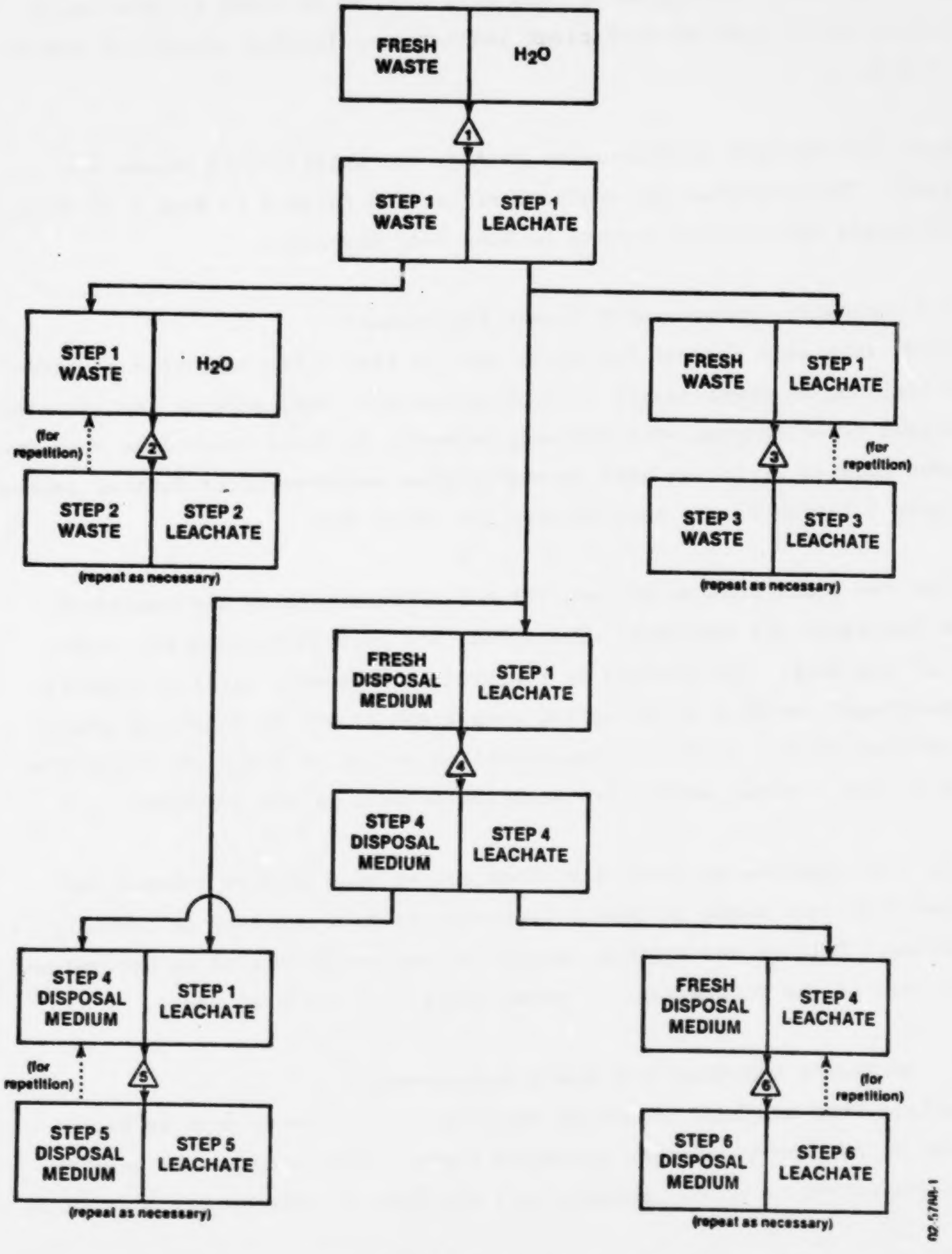

FRESH WASTE
H2O
1
STEP 1 WASTE
STEP 1 LEACHATE
STEP 1 WASTE
H2O
(for repetition)
2
STEP 2 WASTE
STEP 2 LEACHATE
(repeat as necessary)
FRESH WASTE
STEP 1 LEACHATE
3
(for repetition)
STEP 3 WASTE
STEP 3 LEACHATE
(repeat as necessary)
FRESH DISPOSAL MEDIUM
STEP 1 LEACHATE
4
STEP 4 DISPOSAL MEDIUM
STEP 4 LEACHATE
STEP 4 DISPOSAL MEDIUM
STEP 1 LEACHATE
(for repetition)
5
STEP 5 DISPOSAL MEDIUM
STEP 5 LEACHATE
(repeat as necessary)
FRESH DISPOSAL MEDIUM
STEP 4 LEACHATE
6
(for repetition)
STEP 6 DISPOSAL MEDIUM
STEP 6 LEACHATE
(repeat as necessary)
02-57AR-1

Figure 5. Multi-Step Laboratory Leaching Protocol

days and seven days to define the rate and extent of leaching. Only seven-day leachates or leached solids are carried forward to succeeding steps. No pH control is used. Multiples of this step are run in order to measure repeatability and to provide sufficient leachates or leached solids for subsequent steps.

After the required equilibration period, the solid/liquid phases are separated. The leachates are analyzed or carried forward to Step 3 or Step 4. The solids are carried forward to Step 2 or discarded.

Step 2 - Secondary Leaching with Eluant Replacement--

Solids initially leached for seven days in Step 1 are subejcted to additional leaching by fresh eluant (deionized water). This step in the protocol is designed to correspond with leaching behavior in field conditions when replacement volumes of liquid pass through solids residues after initial leaching. Step 2 leachates are equilibrated for seven days.

After the equilibration period, the solid/liquid phases are separated, and the leachates are analyzed. The solids are carried forward for repetition of the step. The process is repeated as necessary until no significant additional leaching is occurring when fresh eluant is placed on previously leached waste. After the equilibration period of the final repetition of Step 2, the residual solids are analyzed as well as the leachate.

Step 2 is repeated at least six times and as many as nine times. Data generated from each waste in Step 1 leachate analyses are used to identify key species. Calcium and sulfate concentrations are monitored as determinative factors in the progression of repetitions with the PFBC waste.

Step 3 - Secondary Leaching with Waste Replacement--

Leachate that has been initially equilibrated for seven days in Step 1 is placed in contact with fresh unleached waste. This step is designed to measure the extent to which leachate will continue to take up key species as it percolates and encounters fresh waste under field conditions. This step also allows determination of whether or not a given species is in a condition of saturation with regard to secondary leaching. Step 3 leachates are equilibrated for both one and seven days. Seven-day leachates are used for repetition of the step.

After the required equilibration period, the solid/liquid phases are separated. The leachates are analyzed or carried forward for repetition of the step. The solids are discarded.

To repeat Step 3, sufficient samples must be set up initially to provide the necessary eluant for the desired number of repetitions. At the end of each repetition, the leachate from two samples is analyzed, and the remainder of the leachates are composited to provide eluant for the next repetition with fresh unleached solids. Figure 6 illustrates the steps necessary to provide six repetitions of the step.

Step 3, in which the number of repetitions must be chosen prior to the initial setting up of the step, is carried out in six repetitions. This number of repetitions has been selected on the basis of time and equipment availability. The use of two rotator devices for each set of repetitions allows six repetitions of protocol. In general, two or three repetitions are necessary for trend definition in secondary leaching.

Determination of Attenuation Capacity of Disposal Media

The attenuation capacity of disposal medium is determined by Steps 4, 5, and 6 of the multi-step laboratory leaching protocol (Figure 4). Step 4 determines primary attenuation and Steps 5 and 6 determine secondary attenuation. The following three sections describe each of these steps in detail.

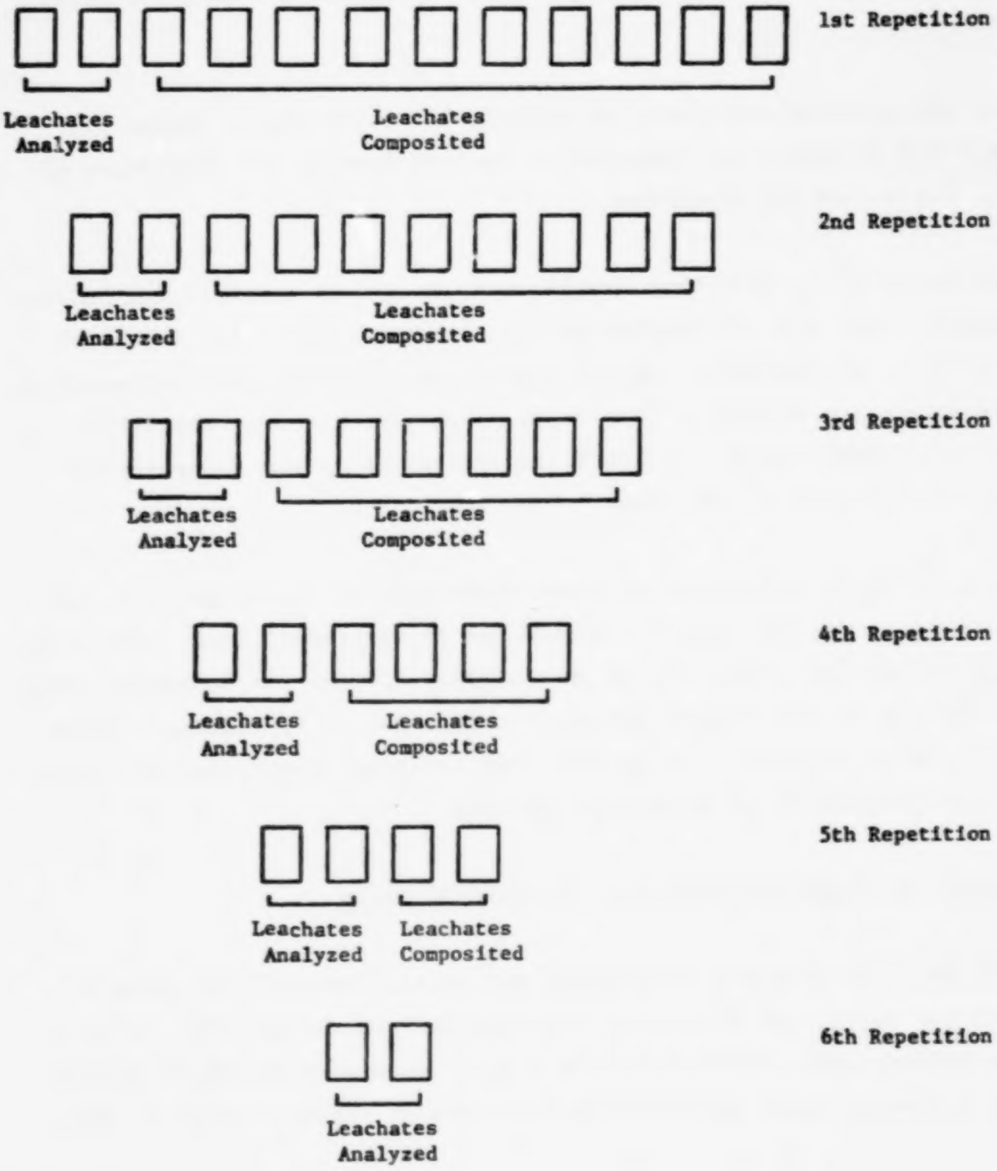

1st Repetition
Leachates Analyzed
Leachates Composited
2nd Repetition
Leachates Analyzed
Leachates Composited
3rd Repetition
Leachates Analyzed
Leachates Composited
4th Repetition
Leachates Analyzed
Leachates Composited
5th Repetition
Leachates Analyzed
Leachates Composited
6th Repetition
Leachates Analyzed

Figure 6. Scheme for Successive Leaching with Solid Replacement

Step 4 - Initial Attenuation by a Disposal Medium--

Leachate that has been initially equilibrated for seven days in Step 1 is placed in contact with an attenuation (disposal) medium for one, two, and seven days. This step is designed to measure the attenuating capacity of a given medium and to allow comparisons among the group of six different media. Analysis of the leachate at the three time intervals permits the determination of both the rate and extent of attenuation.

After the required equilibration period, the solid and liquid phases are separated. The leachates are analyzed or carried forward to Step 6. The solids are carried forward to Step 5 or discarded.

Step 5 - Secondary Attenuation from Burdened Disposal Media in Contact with Leachate--

Solids from Step 4, previously in contact with Step 1 leachate for seven days, are placed in contact with additional leachate from Step 1. This step is designed to measure the capacity of the disposal media to bring about additional attenuation when in contact with fresh leachate.

After the equilibration period, the solid and liquid phases are separated and the leachates are analyzed. The solids are carried forward for repetition of the step. This process is repeated as necessary until no significant attenuation is occurring when Step 1 leachate is placed on a previously burdened disposal medium.

No significant attenuation is occurring when the level of concentration for a given species in the Step 5 leachate approaches the concentration found in the eluant, Step 1 leachate. After the final repetition of Step 5, the residual solids are analyzed as well as the leachate.

Step 5 is repeated at least six times and as many as nine times, depending on evaluation of trends in key species for each individual disposal medium.

Step 6 - Secondary Attenuation with Replacement of Attenuating Medium--
Leachates that have been initially equilibrated for seven days in Step 4 and that contain residual concentrations of key species following initial attenuation are placed in contact with fresh unleached disposal media. This step is designed to determine incremental (secondary) attenuation which may occur.

After the required equilibration period, the solid and liquid phases are separated. The leachates are analyzed or carried forward for repetition of the step. The solids are discarded.

To repeat Step 6, sufficient samples must be set up initially to provide the necessary eluant for the desired number of repetitions. At the end of each repetition, the leachate from two samples is analyzed, and the remainder of the leachates are composited to provide eluant for the next repetition with fresh unleached solids. Figure 6 illustrates the steps necessary to provide the repetitions of the step. The first repetition is actually Step 4.

Step 6 is repeated five times due to equipment and time availability. In general, trends in secondary attenuation are defined by two or three repetitions. Five repetitions allows an extra margin of data for evaluation.

Sample and Apparatus Preparation

Before the laboratory studies are initiated, the materials and apparatus used in the studies are prepared. These initial preparations set the conditions under which the studies are conducted. These preparations include:

- preparation of solids,
- preparation of apparatus, and
- preparation of leaching containers.

After each step in the protocol in completed, samples are prepared for chemical analysis. These preparations include separation of the leachate from the solids and sample preservation. Detailed descriptions of sample and apparatus preparations are given in Appendix II.

Special Studies

Special studies are performed on the wastes and disposal media as a part of the preliminary leaching studies or as needed to initiate the field studies. These studies include an optional extra protocol step and determination of apparent bulk density.

Secondary "Leaching" from a Burdened Disposal Medium by Contact with Fresh Water--

Once an attenuating disposal medium has incorporated species from leachate, there must be concern over its tendency to give up the same species to fresh water at a later time. This tendency is determined by conducting equilibrations for both one day and seven days with "burdened" media from Protocol Step 4 in contact with fresh water. This step is equivalent to Protocol Step 5 but with the use of water instead of Step 1 leachate as the eluant. Chemical analysis of the resulting leachate gives a measure of the tendency of the medium to release a species into the fresh eluant. The procedure is repeated by successive replacement of fresh water to determine when a steady state has been reached in regard to continued species release. This optional additional protocol step, when performed, is referred to as "Step 7." Step 7 studies of PFBC wastes have been performed, and results will be presented in future reports for this program.

Apparent Bulk Density--

This study is required to relate the mixing ratios for the wastes. The bulk density measurements have also been used in data interpretation for the field studies. A measured volume of a representative dried sample is weighed to determine the bulk density (g/mℓ).

Physical Characterization of Wastes

Physical characterization of the wastes is performed to provide information concerning possible controlling physical parameters in the chemical leaching process. Utilizing data from the physical analyses may provide crucial input to aid in interpretation of final chemical data. In addition, an understanding of physical characteristics can be of value in designing disposal practices of waste for maximum protection to the environment. The various physical tests are described below with their anticipated utilization.

X-Ray-Diffraction Analysis--

It is expected that operating conditions of an FBC unit will have an impact on the nature of waste streams. Preliminary studies of fines collected from the primary cyclone of an FBC unit indicate that the bed temperature has a definite effect on the crystallinity of the sample. Differences in crystallinity result in changes in leachability, so interpretation of leachability differences will be aided by X-ray diffraction data. Polycrystalline powder patterns are being obtained for the individual and mixed FBC waste components. Details of the methods used are given in Appendix II.

Scanning Electron Microscopy and Electron Microprobe Analysis--

Scanning electron micrographs of representative portions of FBC wastes are obtained to determine particle morphology, particle size range, and the degree of homogeneity with respect to particle size. Details of the methods used in performing the scanning electron microscope studies are given in Appendix II. Once subsequent leaching data on the various wastes are available, observations will be made about the relation between particle size (and morphology) and leaching tendency. In turn, if correlations exist between FBC unit operating parameters and particle morphology, then optimum conditions related to control of leaching tendency will be known and may be balanced against other factors affecting optimum operating conditions. Electron microprobe analysis of individual particle types provides information regarding distribution of key elements between particles as well as within particles (surface versus bulk localization versus bulk distribution).

Particle Size, Specific Surface Area, and Specific Gravity Analyses--

FBC wastes generated in various waste streams have distinctively different particle size distributions. The heterogeneity in the particle size of the FBC wastes may be extremely important if surface-controlled reactions dominate the chemical interaction between the leachate and the waste. The particle size analysis is performed on each waste ground to the same extent as the samples used in the sequential batch leaching protocol. This particle size information should aid in interpretation of the surface reactions in the laboratory studies. The particle size distribution curves show the cumulative mass percents for equivalent spherical diameter in microns. The data for average particle size analysis and particle size distribution are further illustrated by scanning electron photomicrographs depicting the variation in particle morphologies.

These data are augmented by specific surface area analysis of the wastes. The specific surface area is an important physical parameter since some of the waste properties are influenced by the amount of exposed surface area. A relationship may exist between the specific surface area and both leaching rate and extent for some of the key species being monitored in the leaching experiments. The specific surface areas are measured as the surface area per unit weight of the material, given in square meters per gram.

The specific gravity of the waste is also being determined. The specific gravity is an essential parameter for determining the bulk density of the waste. This parameter is also important in analysis of waste disposal from a volumetric viewpoint. This measurement is given in mass per unit volume, or grams per cubic centimeter.

The average particle size analysis, specific surface area analysis, and specific gravity analysis of the FBC wastes have been performed by Mircomeritics Instrument Corporation. The wastes have been analyzed on a SediGraph Particle Size Analyzer to determine the average particle size. The particle size distribution has been determined by automatic sedimentation using low-energy X-rays to measure concentration at decreasing sedimentation depths with increasing time. The specific surface area has been determined by a modified, single-point Brunauer, Emmett, Teller (B.E.T.) method using nitrogen as the adsorbate on a Specific Surface Area Analyzer. The specific gravity has been determined using an iterative technique of volume comparison and helium for the gas on an Auto-Pycnometer.

Physical Characterization of Disposal Media

Physical characterization studies for the various disposal media are designed to aid interpretation and understanding of their attenuating capacity. Most of the same physical properties determined for FBC wastes are equally important in evaluating the attenuating behavior of the six media. As a result, many of the same instrumental methods of analysis specified in the preceding section are being used. The specification of the principles and operations used for X-ray diffraction, scanning electron microscopy, surface area analysis, particle size distribution, and specific gravity are given in Appendix II.

Liner Compatability Studies

For wastes classified as hazardous under provisions of the Resource Conservation and Recovery Act of 1976 (RCRA), regulations proposed by the Environmental Protection Agency (EPA) will require containment of leachate rather than attenuation in the substrate. Therefore, the liner compatability studies are designed to measure the chemical integrity (compatibility) of candidate liners in continuous and intimate contact with FBC leachate. The long-term integrity is investigated to the maximum extent possible, subject to time constraints of the program. Susceptability of liner materials to chemical attack by leachates will be the key consideration to programs of leachate containment since any satisfactory liner material is assumed to be essentially impermeable to leachates unless degraded in some manner. The liner materials being studied are:

- neoprene,
- polyvinyl chloride (PVC),
- chlorinated polyethylene (CPE),
- hypalon (HYP),
- butyl rubber,
- EPDM rubber, and
- sodium bentonite.

These liner materials have been extensively studied for other types of wastes (industrial, utility, and others), and their relative merits for application have been analyzed in terms of cost, engineering, and availability. Therefore, the focus of attention will be to ascertain if any liners are chemically degraded when in contact with FBC waste leachate.

Studies with Synthetic Polymeric Liners--

The five organic-based liners listed above are placed in contact with equilibrium leachate from PFBC waste. Experimental design is such as to guarantee continuous and intimate contact. Liner integrity is studied by monitoring the following three parameters:

- tensile strength of the liner (ASTM, D412),

- scanning electron microscope observation of the liner surface, and

- total organic carbon (TOC) in the leachate contacting the liner.

Tensile strength and SEM observation are determined for each liner material prior to contact with leachate. Sufficient strips of each liner are placed in contact with leachate to allow three per month (for 18 months) to be removed for measurement of tensile strength (in triplicate) and for SEM observation. Samples are labeled for SEM observation such that the same approximate area is studied both before and after leaching. Every month, an aliquot of the leachate is removed along with the three liner strips and measured in duplicate for total organic carbon (TOC). The combination of three tests listed above should allow an answer to be given in regard to the occurrence of liner degradation over an 18-month time period. These studies have been initiated but not completed during the first year of the program.

Studies with a Bentonitic Clay Material--

A sodium-exchanged Wyoming bentonite with high cation exchange capacity and maximum swelling properties is being placed in continuous and intimate contact with PFBC leachate and the following parameters of clay lattice degradation monitored:

- physical observation by SEM,
- crystalline lattice changes by X-ray powder diffraction, and
- monitoring of aluminum levels in the leachate.

Each month aliquots of both the clay mineral and the leachate are taken and the above parameters determined. SEM and X-ray diffraction allow direct observation of changes in the clay material structure, while an increase of aluminum concentration in the leachate is indicative of chemical attack by the leachate on the clay lattice. Leaching of the clay by a deionized water control followed by analysis for aluminum allows correction for any aluminum contained in an ion-exchange position on the surface rather than lattice aluminum.

Quality Assurance and Quality Control in the Laboratory Studies Task

In the laboratory studies of PFBC waste and its interaction with different disposal media, experiments have been designed to investigate chemical and physical behavior under controlled experimental conditions. This design warrants consistency in operational procedures and in controllable parameters affecting the behavior.

The leaching and attenuation protocols have been designed to achieve optimum reproducibility. Preliminary studies and results from prior investigations have implemented the present design in which special consideration has been given to liquid-to-solid mass ratios, agitation rates and devices, and equilibration periods to provide maximum reproducibility.

Each protocol step is performed in duplicate; some protocol steps are executed in multiple replicates to generate sufficient liquid for successive protocol steps. When multiple replicates are available, both individual and composited liquid samples are analyzed to determine variation in eluants produced in different containers.

In preparation for both leaching and attenuation studies, the same procedures for solids preparation and apparatus preparation are executed to maintain reproducibility. All solids are representatively sampled according to ASTM methods, dried at constant low temperature, and ground to approximately the same particle size. Solid-liquid interactions are carried out with identical agitation devices at a constant rotation velocity for a set amount of time.

Other standard laboratory procedures are also followed to minimize experimental errors. Leachate containers are prewashed in dilute nitric acid and rinsed several times with deionized water to deter container contamination. Each solid and liquid is handled carefully in the same operational manner each time a sample is divided, preserved, or carried forward to successive protocol steps. Care in labeling and prompt analyses follow each phase of leaching and attenuation.

FIELD STUDIES

A major goal of this study is to attempt to simulate an FBC waste landfill as closely as possible by using large diameter, disturbed-media field cells. The field studies provide the basis for a logical bridge between results of laboratory batch equilibration tests and waste behavior in a full-scale, operating disposal facility. The primary experimental tool is a set of large-diameter columns containing a combination of FBC wastes and disposal media. The test matrix for the field cells is shown in Table 4. These field cells are constructed and operated to simulate "quasi-field" conditions. The major phenomena modeled in the field that are not modeled in the laboratory are:

- unsaturated flow,
- intermittent input from rainfall, and
- seasonal temperature fluctuation.

The results of the field cell test phase are a series of observations (throughput volumes, chemical analyses of samples) over time that reflect the effects of a natural climatic pattern on a representative waste disposal system. The results of the field studies conducted during the first year are reported with the laboratory results in Sections 4 and 5 of this report.

Study Sites

The field studies are conducted primarily in Crown, West Virginia, but the initial phases of the field studies were conducted at Radian facilities in Austin, Texas.

Radian Facility--

Radian's facility was used for construction and trial operation of a prototype field cell (described below). This provided an economical and efficient means of ensuring smooth construction and operation procedures at Crown. Small laboratory control (media only) columns have also been constructed and operated in Radian's Austin facility.

Crown Field Site--

The site selected for the construction and operation of the field cells is the former EPA Mine Drainage Control Field site at Crown (unincorporated),

TABLE 4. TEST MATRIX FOR FIELD CELLS AT CROWN, WEST VIRGINIA

Disposal Medium	Control Cell	B&W[1] AFBC Recycle	Georgetown[2] AFBC Recycle	Exxon[3] PFBC	Total Cells
Limestone		1		1	2
Sandstone			1	1	2
Shale	1	1		2	4
Alluvium	1	2	1	1	5
Interburden		1	1		2
Glacial Till	—	—	1	1	2
TOTALS	2	5	4	6	17

[1] B&W AFBC Recycle: Babcock and Wilcox Atmospheric Fluidized Bed Combustor (AFBC), Alliance, Ohio, operated in a recycle mode.

[2] Georgetown AFBC Recycle: Pope, Evans, and Robbins/Foster Wheeler Institutional Boiler AFBC, Georgetown University, Washington, D.C.

[3] Exxon PFBC: Exxon Miniplant, Linden, New Jersey.

West Virginia, approximately nine miles southwest of Morgantown in Monongalia County. The site is in a small valley at roughly 1,000 feet in elevation. The surrounding hills rise to 1,200 to 1,300 feet elevation. The field cells are constructed in an open, gently sloping field. The nearest obstructions are two one-story buildings approximately 50 feet away.

The climate of the Crown site is "humid continental", with severe winters, moderately hot summers, and precipitation evenly distributed throughout the year. A climatological summary for a nearby National Weather Service Cooperative station at Mannington, West Virginia is presented in Table 5. In addition to these data for Mannington, pan evaporation data are available for the Clarksburg, West Virginia weather station, and are presented in Table 6. Rainfall data are being collected at the Crown site during this program and are presented in a later section.

Selection and Acquisition of Disposal Media

Disposal media were selected to meet two criteria. First, the materials should be selected from the class of likely disposal site substrates. Second, the materials should represent as broad a range of hydraulic and geochemical conditions as practicable. The six media selected are:

- shale, with minor sandstone;
- sandstone, with minor shale;
- alluvium;
- glacial till;
- limestone; and
- coal seam interburden.

Natural materials were chosen, rather than synthetic substrates. For example, the limestone is run-of-the-quarry, rather than, say, technical grade $CaCO_3$.

The shale, till, sandstone, and alluvium are all ubiquitous surface or near-surface materials. They form a crude continuum of fine grained (less

TABLE 5. CLIMATOLOGICAL SUMMARY FOR MANNINGTON, WEST VIRGINIA[7]

LATITUDE N39 33
LONGITUDE W80 21

CLIMATOLOGICAL SUMMARY

MEANS AND EXTREMES FOR PERIOD 1951-1973

MANNINGTON 1 N, WV
ELEVATION 975

MONTH	TEMPERATURE (°F)													PRECIPITATION TOTALS (INCHES)														
	MEANS			EXTREMES						MEAN NUMBER OF DAYS										SNOW, SLEET						MEAN NUMBER OF DAYS		
										MAX.		MIN.																
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	90° AND ABOVE	32° AND BELOW	32° AND BELOW	0° AND BELOW	MEAN	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	MEAN	MAXIMUM MONTHLY	YEAR	GREATEST DEPTH	YEAR	DAY	.10 or MORE	.50 or MORE	1.00 or MORE
JAN	40.7	18.3	29.5	78	59	21	-26	63	29	0	8	27	3	2.97	5.56	52	1.99	53	8	10.1	21.5	66	15.0	66	30	8	2	0
FEB	43.5	20.9	32.2	74	72	29	-18	68	21	0	5	24	2	2.89	5.10	56	1.70	51	1	7.9	23.5	64	15.0	66	5	8	1	0
MAR	53.8	27.7	40.8	85	73	15	-12	60	8	0	1	22	0	3.72	7.07	63	1.95	67	6	6.0	18.5	60	12.0	60	5	9	3	1
APR	66.8	37.0	51.9	91	70	30	11	64	1	0	0	11	0	3.70	6.12	73	1.55	64	20	1.0	6.3	73	4.0	73	12	9	2	0
MAY	76.2	45.4	60.8	93	62	16	20+	66	10	1	0	3	0	4.15	9.75	68	3.42	56	27	.0	1.0	63				9	3	1
JUN	83.4	54.3	68.9	97	52	29	30	72	11	5	0	0	0	4.06	9.02	56	4.10	56	25	.0						7	3	1
JULY	85.9	58.7	72.3	99	66	3	36	63	4	8	0	0	0	4.60	8.42	58	3.27	52	4	.0						8	4	1
AUG	84.6	57.3	71.0	100+	53	30	37	65	29	5	0	0	0	4.39	10.07	54	2.86	58	14	.0						7	3	1
SEPT	79.3	50.2	64.8	102	53	3	21	62	21	3	0	1	0	3.19	7.98	71	2.60	71	12	.0						6	2	1
OCT	68.5	38.3	53.4	92	51	3	13+	65	29	0	0	9	0	2.59	6.82	54	3.50	54	15	.3	3.7	57	3.0	57	28	6	1	0
NOV	54.3	29.9	42.1	84	61	3	-2	58	30	0	1	19	0	2.89	5.27	51	1.45	61	24	2.6	9.5	71	5.0	67	30	7	2	0
DEC	43.8	22.9	33.4	77	51	7	-22	62	13	0	5	24	1	3.35	6.33	72	1.47	72	9	8.3	25.5	62	15.0	62	11	8	2	0
YEAR	65.1	38.4	51.8	102	SEP 53	3	-26	JAN 63	29	22	20	140	6	42.48	10.07	AUG 54	4.10	JUN 56	25	36.2	25.5	DEC 62	15.0	DEC 62	11	92	28	6

+ ALSO ON EARLIER DATES

TABLE 6. AVERAGE MONTHLY PAN EVAPORATION FROM CLARKSBURG, WEST VIRGINIA WEATHER STATION (U.S. WEATHER BUREAU 1930-1962)

Month*	Evaporation (inches)
April	3.48
May	4.58
June	5.21
July	5.56
August	4.49
September	3.14
October	1.90
SEASON TOTAL	28.36

*Pan evaporation from November through March is inconsequential.

permeable) to coarse grained (more permeable) materials, representing both consolidated and unconsolidated strata. The limestone and interburden provide alkaline and acidic geochemical end members (extremes), respectively, and also simulate disposal in a limestone quarry or a coal mine. These six media represent a relevant and credible set of candidate disposal site substrates.

Within the guidelines established above, media were acquired from the nearest available sources to Crown, West Virginia. Formations quarried and locations are listed in Table 7.

The shale, sandstone, and interburden were all obtained from the Christopher No. 3 Mine, Monongalia County, West Virginia, which is operated by the King Knob Coal Company, Clarksburg, West Virginia. Formations above the Waynesburg coal had been blasted and were being removed by scoop loader and truck. Material from the blasted section was merely loaded out and removed to stockpiles at the field site. Where the shale parting in the Waynesburg was thick enough (greater than one foot), it was being separated from the coal in the pit. The interburden sample was taken from a stockpile of this material and contains a significant amount of coal fragments.

The limestone is crushed (AASHO #9) limestone purchased from the Greer Limestone Company, Greer, Monongalia County, West Virginia. By coincidence this material is also the bed material feedstock for the FBC boiler at Rivesville, West Virginia.

The nearest region that has undergone extensive glaciation is central Ohio. To obtain glacial till, an excavation contractor was located in Union County, north of Columbus, Ohio. An excavation project was under way in a deep Wisconsin age ground moraine. The material was inspected and deemed suitable. Sufficient material was removed from the 2 to 8 foot depth zone (avoiding the root zone) and transported to the field site. This particular till, reflective of the limestone bedrock in the area, is a high-lime till.

Extensive alluvial deposits do not occur in the upper Monongahela River Basin. The nearest source is the Ohio River Valley along the Ohio and West

TABLE 7. SOURCES OF DISPOSAL MEDIA

Medium	Formation (age)	Quarry Location
Shale	Cassville Shale Member of Dunkard Group (Permian)	39°36'N, 80°03'W
Sandstone	Waynesburg Ss of Dunkard Group (Permian)	39°36'N, 80°03'W
Alluvium	Ohio River Valley floodplain deposit (Quaternary/Recent)	39°31'N, 81°04'W
Glacial Till	Ground moraine from Wisconsin glaciation (Quaternary)	40°12'N, 83°21'W
Limestone	Greenbrier Ls (Mississippian)	39°34'N, 79°51'W
Interburden	Shale parting in Waynesburg (Upper Pennsylvanian coal)	39°36'N, 80°03'W

Virginia border. No current excavation projects were located, so stockpiled overburden from a conveniently located sand and gravel operation was procured.

Field Cell Design and Construction

Cell Design--

The waste/medium geometry of the field cells is a layer of waste over a layer of disposal media (Figure 7). Above the waste is another layer of disposal media. With the exception of the sand layer below the waste, a modification necessary for proper sampling, these cells provide a reasonable simulation of an FBC landfill site. The container is an 8-foot section of reinforced concrete pipe, 48 inches in diameter, which is the largest readily available size. The field cells are as large as practicable in order to minimize edge effects and to reduce the impact of inadvertent segregation of material during placement. They are of sufficient scale that field simulation conditions are satisfied with reasonable construction and waste requirements. The diameter chosen, 48 inches, provides a significant increase over common laboratory scale. A large laboratory column might be 8 inches in diameter; the field cells have a cross sectional area 36 times as large.

Installed in each field cell is a leachate sampling system. Immediately below the waste body is an array of porous cup samplers (upper sampling array of Figure 7) to sample leachate before it enters the underlying media. Below the disposal medium is a second set of porous cups (lower sampling array of Figure 7) to sample leachate after it has interacted with the media. In the center of each array is a ceramic block soil moisture sensor; it is used to detect the presence or absence of significant quantities of water. Additionally, a perforated pipe gutter is emplaced immediately above the waste body. Should infiltrating water perch atop the waste, it can be sampled by pumping out this gutter.

Cell Construction--

Field cells are erected in a ring of six around a seventh, larger, central cylinder, which serves as an equipment shelter and provides access for sampling, as shown in Figure 8. The equipment shell is furnished with six

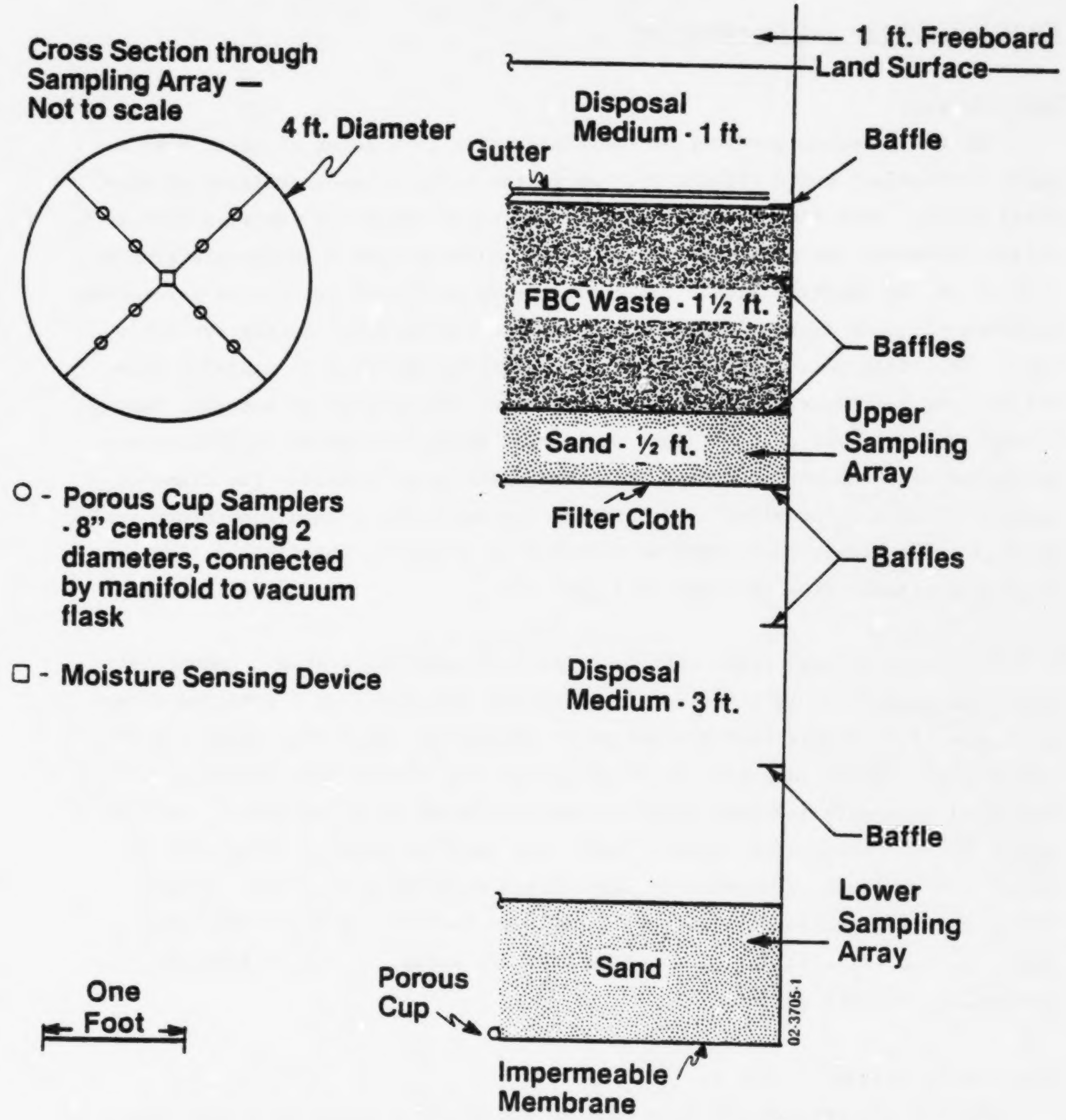

Cross Section through
Sampling Array —
Not to scale
4 ft. Diameter
O - Porous Cup Samplers · 8" centers along 2 diameters, connected by manifold to vacuum flask
□ - Moisture Sensing Device
One
Foot
1 ft. Freeboard
Land Surface
Disposal
Medium · 1 ft.
Gutter
Baffle
FBC Waste · 1½ ft.
Baffles
Sand · ½ ft.
Upper
Sampling
Array
Filter Cloth
Baffles
Disposal
Medium · 3 ft.
Baffle
Lower
Sampling
Array
Sand
Porous
Cup
Impermeable
Membrane
02-3705-1

Figure 7. Field Cell Geometry

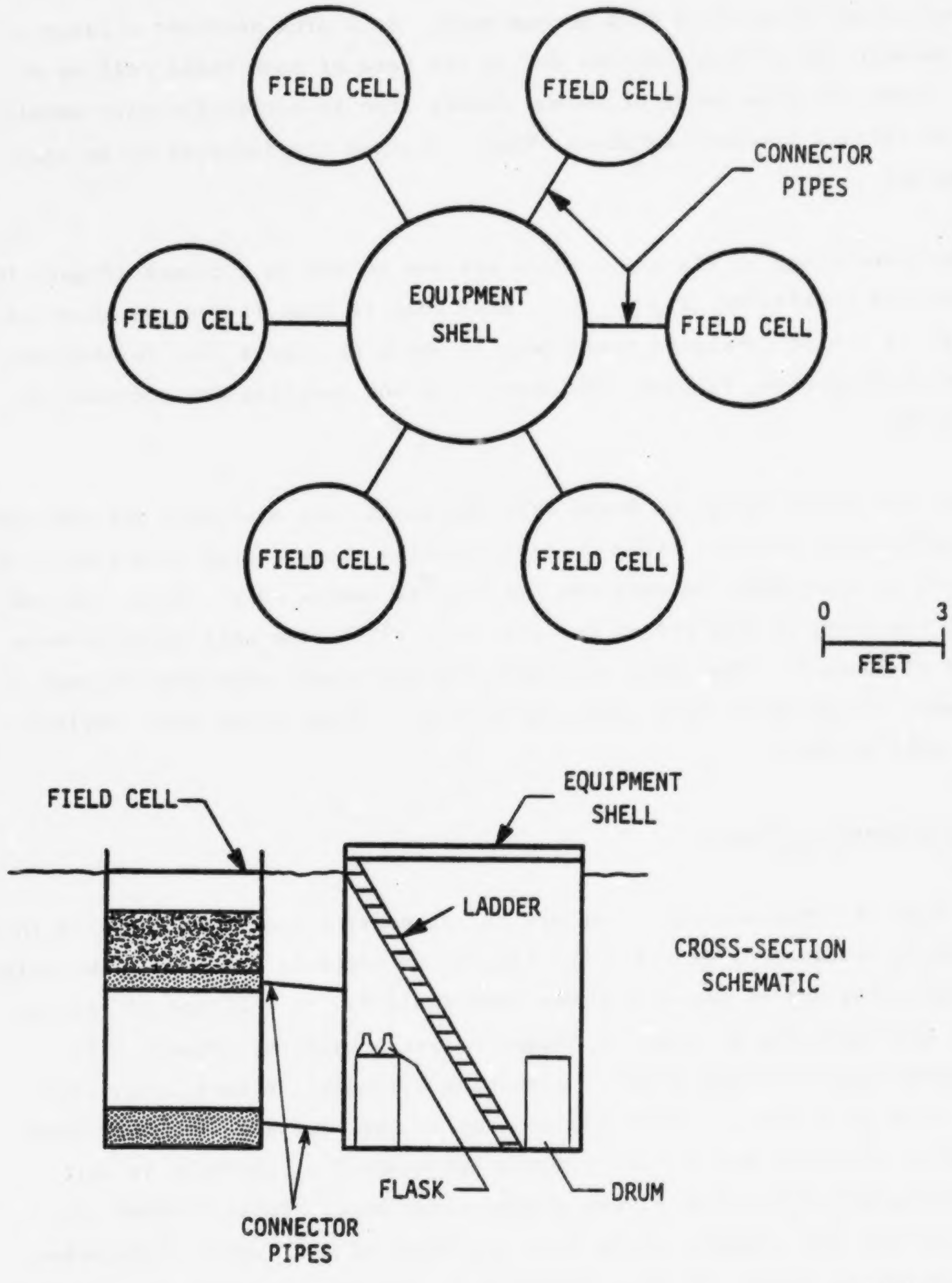

FIELD CELL
FIELD CELL
CONNECTOR PIPES
FIELD CELL
EQUIPMENT SHELL
FIELD CELL
FIELD CELL
FIELD CELL
0
3
FEET
FIELD CELL
EQUIPMENT SHELL
LADDER
CROSS-SECTION SCHEMATIC
FLASK
DRUM
CONNECTOR PIPES
02-4415-1

Figure 8. Field Cell Arrangement

drums connected by manifold to a vacuum pump. Each drum services a large porous ceramic cup (filter candle) set in the base of each field cell as a drain. There are also racks of vacuum flasks (two in series for each sample point) to collect leachate samples. Figure 9 shows the interior of an equipment shelter.

The three rings of six field cells are set on end in a trench (Figure 10), which is then backfilled (Figure 11). Each cell is then filled, as shown on Figure 8. A single completed field cell is shown in Figure 12. Further details of construction, filling, and operations and sampling are provided in Appendix II.

Only one waste, from the Exxon PFBC Miniplant, was available for the current construction season. Field cells containing these wastes were completed and placed in operation, as were the two control (media only) cells. At the close of the construction effort to date (July 1979), the cell contents were as shown on Table 8. The cells with no waste shown were completed through emplacement of the upper sand layer and covered. These cells await emplacement of AFBC wastes.

Laboratory Control Columns

In lieu of constructing a complete set of control (media only) cells in the field, a combination of field and laboratory controls are used. Two full-size field cells are in place at Crown (see Table 8). A full set of columns with all six media are in place in Radian's Austin facility (Figure 13). These columns are six-inch diameter plexiglas cylinders, 6 feet long, containing a six inch lift of inert silica sand at the base and a roughly five-foot lift of disposal media. The columns are mounted verticially in wall racks, and sample collection flasks placed under each. Table 9 shows the contents of the six columns, along with the depth of media after irrigation. Media were merely poured dry into the columns, not packed, which is analogous to the filling procedures at Crown. A single porous ceramic cup at the base serves as both a bottom drain and sample collection device. The laboratory columns are not fitted with baffles, as are the field cells. Should channel-

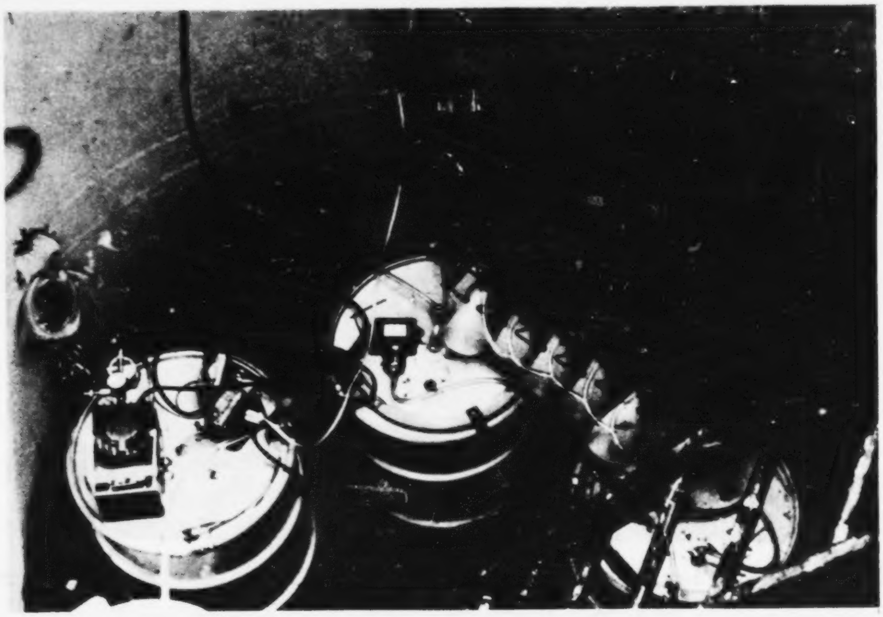


Figure 9. Interior of Equipment Shelter, Showing Drums For Botton Drains and Flasks for Sample Collection

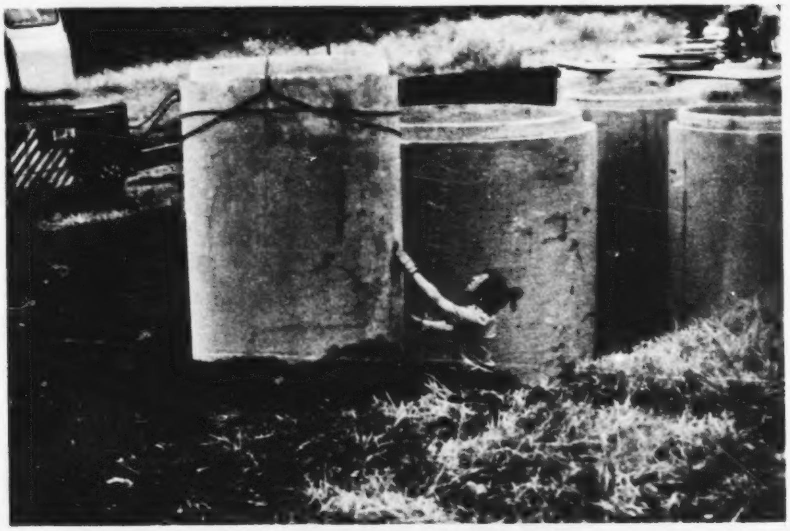


Figure 10. Shells for Field Cells Being Lowered Into Trench

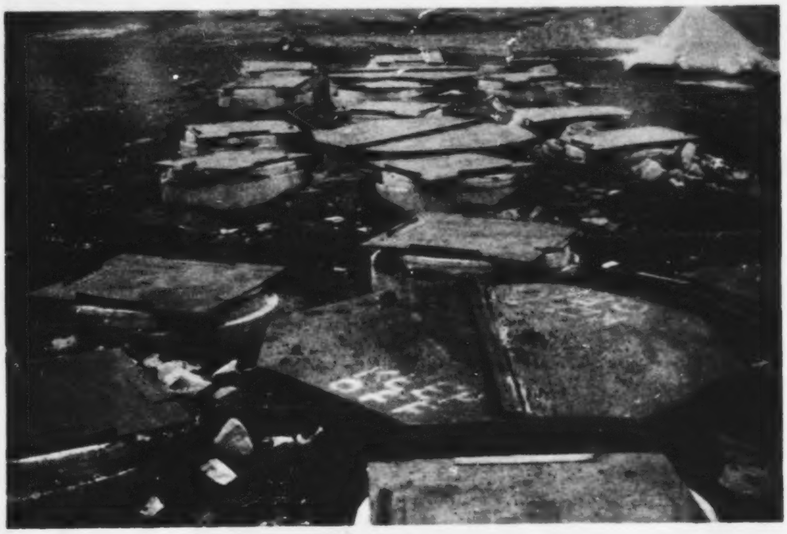


Figure 11. View of Completed Field Cell Installation. Temporary Covers are Still in Place

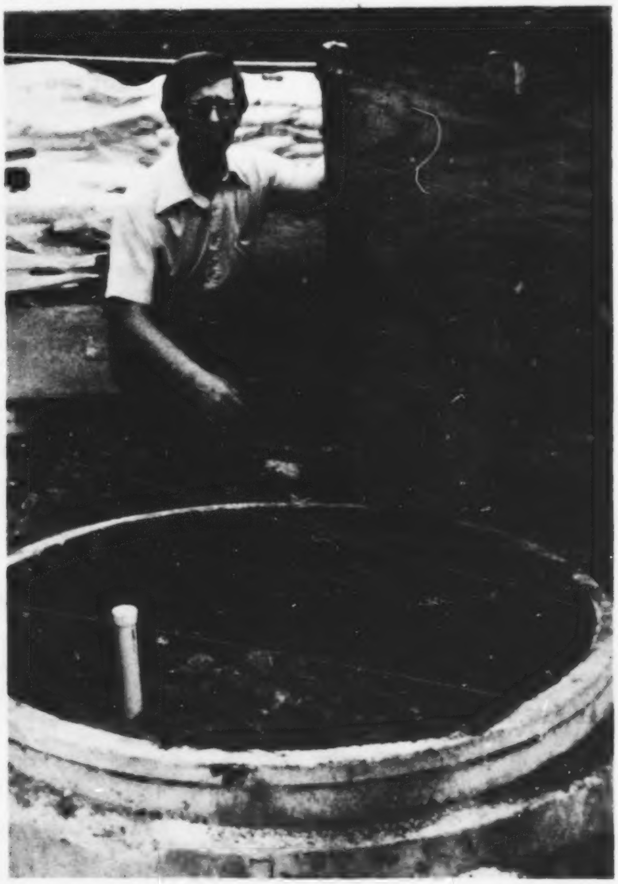
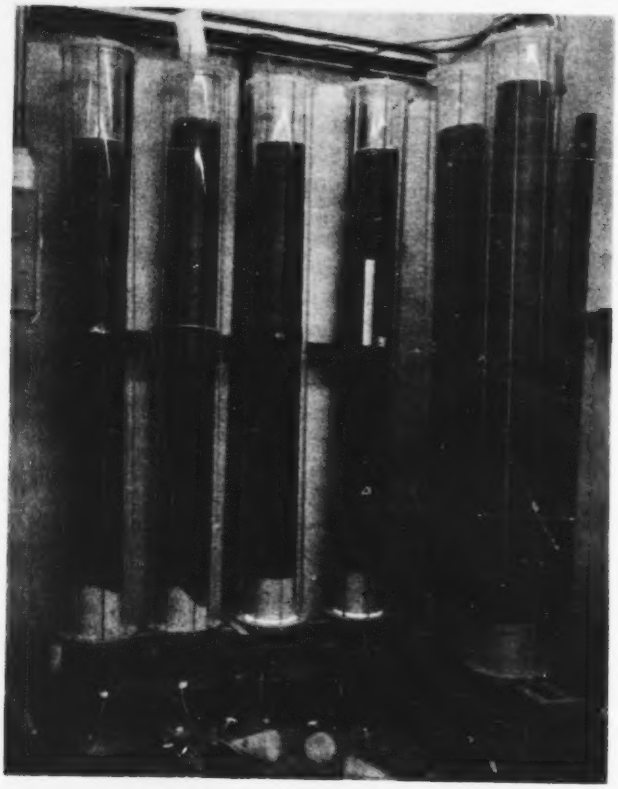


Figure 12. Completed Field Cell

TABLE 8. FILLING SCHEDULE - CROWN CELLS

Field Cell Number	Medium	Waste
1	Shale	Exxon PFBC
2	Shale	Exxon PFBC
3	Glacial Till	Exxon PFBC
4	Limestone	Exxon PFBC
5	Alluvium	Exxon PFBC
6	Sandstone	Exxon PFBC
7	Shale	None (Control)
8	Sandstone	NF[1]
9	Alluvium	NF
10	Interburden	NF
11	Glacial Till	NF
12	Alluvium	None (Control)
13	Interburden	NF
14	Alluvium	NF
15	Alluvium	NF
16	Limestone	NF
17	Shale	NF
18	None (Spare Cell)	None (Spare Cell)

[1] NF = Not yet filled; awaiting waste availability.



NOTE: One-foot ruler on center column
indicates scale.

Figure 13. Laboratory Control Column

ing along the walls occur, it can be observed through the clear plexiglas. The media could then be repacked, as required.

TABLE 9. LABORATORY CONTROL COLUMNS

Column	Medium	Depth (inches)
A	Sandstone	56
B	Shale	62
C	Alluvium	58
D	Interburden	58
E	Limestone	61
F	Till	63

The laboratory columns are operated in parallel with the Crown cells, but delayed by 54 days. Records of daily rainfall depths at Crown are converted to equivalent volumes and each column is irrigated with that volume of deionized water. The porous ceramic cup at the base is kept under a constant 0.3 atmosphere vacuum to quantitatively remove all leachate generated and to ensure unsaturated flow. Because of the smaller volumes involved (182 ml per mm of rainfall), each 500 ml aliquot of leachate collected is split and submitted for analysis.

Quality Assurance and Quality Control for Field Studies

The experimental design of the field studies task includes several quality assurance and quality control elements. The test matrix for the field cells was presented as Table 5. This matrix includes two sets of duplicate cells, as shown in Table 10. Results of leachate analyses from these two sets of cells will be compared with one another to evaluate cell-to-cell variation.

TABLE 10. REPLICATE CELLS FOR QA/QC

Field Cells	Waste	Medium	Corresponding Control (Field, Laboratory)
1, 2	Exxon PFBC	Shale	7, B
14,* 15*	B&W AFBC	Alluvium	12, C

*Not completed.

The experimental design also provides for a combination of field and laboratory controls. As noted, a complete set of control (media only) columns are being operated in Radian's Austin facility with a deionized water input equivalent to the Crown rainfall. Two full-size control cells are in place at Crown. Analytical results will be used to determine contaminant contributions from the media themselves, when leached by rainfall or by FBC leachate. The results from the field control cells will also be compared with those of their corresponding laboratory columns as a measure of the equivalence of the control data.

CHEMICAL ANALYSES

Chemical analyses have been performed for leachate samples from field and laboratory studies. The specific sample sources, the species and parameters designated for analysis, and the analytical methods selected for the study are described in this section. The chemical analytical results of laboratory and field studies are given in Sections 4 and 5 of this report.

Sample Sources

The samples to be characterized during the program include the leachate generated from solid wastes and media-attenuated leachates from both field and laboratory tests. The respective solid wastes and media (both before and after being subjected to the various lab and field leaching tests) are also being analyzed. To date, the effort has been directed toward analysis of leachates while awaiting additional FBC wastes to be included in the studies. The specific leachates analyzed are described in the following subsections.

Leachates from Laboratory Batch Equilibration Tests--

Leachates from the six laboratory protocol steps are analyzed for several chemical parameters which are described below. To date, approximately 360 leachate samples representing contact with PFBC waste and six media have been characterized in laboratory studies.

Leachates from Field Cells--

Leachate samples from six field cells containing PFBC waste and disposal media and two control cells containing disposal media only have been characterized for 16 sampling events during the first 72 days of operation. Samples are collected at the upper and lower points of the field cells to define water quality of the raw leachate from the waste and of leachate after exposure to by the disposal media. Samples collected from the media control cells define background concentrations of contaminants contributed by the media. Analyses have been performed thus far for 224 field cell leachate samples.

Leachates from Laboratory Columns--

Leachate samples from laboratory columns containing each of the six disposal media will be characterized for sample events according to the same schedule adopted for the field cells but with a 54-day lag.

Parameters of Analysis

During the program development efforts, an analytical screening was conducted to define parameters of interest for routine chemical analysis. Seven-day PFBC leachates from Protocol Step 1 were analyzed for a broad range of parameters. Table 11 presents the analytical results for six replicate PFBC leachates. The mean of observations for each parameter is also presented. The

TABLE 11. PRELIMINARY ANALYTICAL SCREENING RESULTS
(STEP 1, SEVEN-DAY PFBC LEACHATE)

Parameter*	REPLICATE SAMPLE NUMBER						Mean
	1701A	1701B	1701C	1701D	1701E	1701F	
As	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ba	0.16	0.21	0.14	0.12	0.16	0.18	0.16 ± 0.03
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr	0.029	0.079	0.054	0.205	0.054	0.005	0.07 ± 0.07
Pb	0.0020	0.0021	0.0020	0.0018	0.0024	0.0049	0.0025 ± 0.0012
Hg	<0.0005	<0.0005	—	—	—	—	<0.0005
Se	0.012	0.013	0.012	0.012	0.013	0.009	0.012 ± 0.001
F	0.82	0.74	0.91	0.77	0.72	0.67	0.77 ± 0.08
NO_3-N	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ag	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cl	7.4	2.5	2.6	2.6	2.0	2.4	3 ± 2
Cu	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe	0.39	0.21	0.25	0.18	0.16	0.10	0.22 ± 0.10
Mn	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
pH	12.0	11.9	11.5	11.8	11.6	11.6	11.7 ± 0.2
SO_4	1210	1240	1260	1240	1210	1260	1240 ± 23
TDS	—	3770	—	—	—	—	3770
Zn	0.09	0.21	0.30	0.11	0.10	0.13	0.16 ± .08
Al	0.97	0.66	0.70	0.45	0.37	0.29	0.58 ± 0.25
Be	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
B	11	15	12	15	14	11	13 ± 2
Co	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Li	0.06	0.06	0.06	0.06	0.06	0.03	0.06 ± 0.01
Mo	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CN	<0.1	—	<0.1	—	—	—	<0.1
TOC	1.1	—	—	—	—	—	1.1
Ca	1600	1900	1540	1340	1660	1670	1620 ± 180
Mg	6.3	0.89	0.58	1.6	0.75	0.62	1.8 ± 2
Na	15.4	15.0	14.8	14.8	15.0	10.9	14 ± 2
K	19	19	19	19	19	11	18 ± 3
Sr	2.8	4.0	1.4	1.0	2.1	2.8	2.4 ± 1
Ti	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Si	1.3	0.81	0.65	0.75	0.58	0.39	0.7 ± 0.3
Conductivity**	9500	9500	9500	9700	9500	9500	9530 ± 80

* Concentration in mg/ℓ

** Units are µmhos/cm

mean concentration of each parameter was compared with the primary and secondary drinking water regulations and with the Discharge Multimedia Environmental Goals for both health and ecology.[8,9,10] Species present at levels greater than 0.1 of any regulation or criterion were selected for routine inclusion in the program. The species selected are shown in Table 12. Total organic carbon (TOC) was added to monitor the organic content of the leachate.

Additional FBC wastes for this program will be screened in a similar manner. Analyses will be performed for the parameters shown in Table 12. In addition, initial leachates will be screened for the species shown in Table 13. If insignificant concentrations of certain elements are found in the waste leachate, the elements will be deleted from the list for routine analysis.

Analytical Methods

The analytical methodologies have been selected based upon their accuracy, precision, detection limits, availability, and flexibility in monitoring additional species at minimum additional expenses.

Elemental Analysis by Inductively Coupled Argon Plasma Emission Spectroscopy (ICPES)--

Inductively coupled argon plasma emission spectroscopy (ICPES) was chosen as the primary technique for elemental analysis. The method was selected for its accuracy, precision, and cost-effectiveness. ICPES provides rapid turnaround time associated with simultaneous (multi-element) analysis capability. Initial tests have been performed with an Applied Research Laboratories Model 137. Appendix II presents data for the precision of the instrument used.

Elemental Analyses by Atomic Absorption Spectrometry (AAS)

Atomic Absorption Spectrometry (AAS) is used for analysis of elements requiring lower detection limits than provided by ICPES or for elements without analysis channels on the ICPES. Those elements include mercury, lithium, and selenium. Leachates of new wastes require AAS screening for arsenic and lead. Analyses are performed in accordance with EPA methodology documented

TABLE 12. LIST OF CHEMICAL PARAMETERS INCLUDED IN ROUTINE LEACHATE ANALYSES

- Aluminum
- Barium
- Boron
- Cadmium
- Calcium
- Chromium
- Cobalt
- Fluoride
- Iron
- Lithium
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sulfate
- Vanadium
- Zinc
- pH
- Total Dissolved Solids
- Total Organic Carbon

TABLE 13. ADDITIONAL PARAMETERS TO BE SCREENED IN LEACHATES FROM FUTURE WASTES

- Arsenic
- Beryllium
- Copper
- Lead
- Magnesium
- Manganese
- Molybdenum
- Silicon
- Strontium
- Titanium

in publications of the USEPA-ESML facility in Cincinnati, Ohio.[11] Table 14 lists the specific methodology employed.

TABLE 14. AAS METHODOLOGY FOR ANALYSIS OF LEACHATE QUALITY

Flame	Graphite Furnace	Cold Vapor	Hydride Generation
Li	Pb	Hg	Se As

The atomic absorption analyses are performed with the following instruments:

- Perkin Elmer 403AA,
- Perkin Elmer 503AA,
- Instrumentation Laboratories 351AA,
- Perkin Elmer HGA-2000 Graphite Furnace, and
- Instrumentation Laboratories IL555 Graphite Furnace.

Calibration standards are prepared fresh and analyzed each day to ensure proper calibration and instrument operation.

Other Methods of Analysis--

Leachate samples are analyzed for additional parameters including fluoride, pH, sulfate, specific conductance, total dissolved solids (TDS), and total organic carbon (TOC).

Fluoride is measured by specific ion electrode using the method of standard additions. A citric acid buffer is added to release complexed fluoride and to provide constant ionic strength and pH. The change in potential observed upon addition of a known amount of fluoride is proportional to the original fluoride concentration.

A Corning Model 130 pH meter is used to electrometrically determine the pH of each leachate sample. The meter is calibrated at a pH of 7.0 and either 4.0 or 10.0, depending upon the pH of the samples to be analyzed.

Sulfate is determined by ion chromatography with a Dionex Model 15. Ion chromatography combines three separate techniques -- ion exchange, liquid chromatography, and conductimetric detection -- to partition the ions for subsequent detection. Ion chromatography will not only quantify sulfate, but will also allow monitoring of chloride, fluoride, nitrate, and possibly other anions which are susceptible to fluctuation during field cell studies.

Specific conductance is measured electrometrically with a Lab Line Model 11000 conductance meter over a range of 0.01 to 1,000,000 micromhos per centimeter. A temperature compensator automatically corrects conductivity values to 25°C. The instrument measures the capacity of a liquid to conduct an electric current which is related to the total concentration of ionized substances in the solution.

For determination of TDS, an aliquot of filtered sample is placed in a tared beaker and evaporated to dryness at 105°C. The beaker is reweighed to determine dissolved mass per volume of leachate solution.

Leachate samples are analyzed for TOC with a Dorhmann Model 521D organic carbon analyzer utilizing a flame ionization detector to provide linear response up to 10 μg/mℓ carbon concentration.

Quality Assurance and Quality Control for Chemical Analysis

The aspects of quality control which are employed include:

- calibration of instruments,
- analysis of spiked synthetic and leachate samples,
- analysis of standard samples of known concentration to validate measurements, and
- replicate measurement in the laboratory.

Specific quality control methods used are described in Appendix II.

DATA MANAGEMENT AND INTERPRETATION

The purpose of this section is to discuss the data base management and data analysis for the project. For the field cells, laboratory columns, and laboratory batch equilibration tests, data are received for inclusion in the data base in several forms. For the batch equilibration tests, data are received separately for:

- ICPES elemental analyses,
- AAS elemental analyses, and
- other chemical analyses.

For the field cells, data are received separately for:

- ICPES elemental analyses,
- AAS elemental analyses,
- other chemical analyses,
- flow-through volume, and
- rainfall.

For the laboratory columns, the same three classes of chemical analyses are performed, and the flow-through volume is measured. The laboratory columns are subjected to the same amount of "rainfall" in depth as are the field cells but at a later date (by 54 days).

Each time a set of data is received (e.g., a set of ICPES analyses for batch equilibration tests), it is stored on the computer with the necessary identifying information so that it can later be combined with the other types of information for the same batch equilibration tests. Thus, it is not necessary to wait until the data for a batch equilibration test (or field cell or laboratory column) are complete to edit or begin to analyze the data which are available.

In the following subsections, discussions of the software system being used for data base management and statistical analysis, the field cell data base, and the laboratory batch equilibration test data base are presented. The data management system is described in further detail in Appendix II.

SAS System

The data management and statistical analysis are being performed by using the SAS software system,[12] which is being accessed through a time-sharing computer service. SAS is very flexible and provides a wide variety of capabilities, and its use greatly facilitates the efficient provision of software needs for the project. The SAS system has capabilities for data management, data display (printing tables and line-printer plots), and a variety of statistical analyses. Additionally, SAS can be used to program any additional method which can be formulated in matrix terms.

Field Cell and Laboratory Column Data Base

The chemistry data are received in sets separately from three sources -- ICPES elemental analyses, AAS elemental analyses, and all other chemical analyses. Each time a set of data is received, it is stored along with the codes for the field cell or laboratory column, sampling point (upper or lower collection point), and the date (month, day, and year) the sample was collected. Thus, data for, say, the upper collection point for field cells for a given data from the ICPES, from the AAS, and from other chemical analyses can readily be merged.

The rainfall data, which apply to all field cells, are stored in a separate file on the computer. The rainfall is stored as depth in millimeters on each day, but this can easily be transformed to volume of rainfall into each field cell or to cumulative rainfall in any desired units. The rainfall data can be merged with the chemistry data by date if this is desired.

The same approach is being used for the "rain" to which the laboratory columns are being artificially exposed.

Similarly, the volumes of leachate in the upper collection point, the lower collection point, and the barrel are collected each time a leachate sample for chemical analysis is collected from a field cell. The control field cells (7 and 12) and the laboratory columns have no waste and, hence, no upper collection point. The barrel volume is the total volume which flows through the cell excluding that removed at the collection points. These volumes are also stored by date of collection and field cell or laboratory column code. Hence, the volume data can be merged with the chemistry or rainfall data.

Laboratory Batch Equilibration Test Data Base

As with the field cell and laboratory column data, chemical analyses are received in sets separately from three sources, ICPES elemental analyses, AAS elemental analyses, and all other chemical analyses. The chemistry data are stored along with the necessary codes so that different chemical analyses for the same shake test can be merged. This information includes a code for leachate versus disposal medium sample, laboratory protocol step number (Protocol Steps 2, 3, 5, and 6 involve successive leachings and this index allows those leachings to be put in sequence), leaching time in days (1, 2, or 7), waste type code, disposal medium code, and a code indicating which of two or more replicate performances of a particular shake test the sample is from.

CONCEPTUAL MODEL DEVELOPMENT

As noted in Section 1, one of the two major objectives of this program is to develop a methodology or conceptual model that may be employed at each proposed future FBC waste disposal site. The purpose of this methodology is to ensure that environmental protection is attained at each site by taking into account the various site-specific factors that will vary greatly from site to site. It is envisioned that this conceptual model will consist of a rigorous protocol of steps or procedures that will require the input of data concerning the characteristics of the site (e.g., slope, lithology of the substrate above and below the water table, depth to the water table, baseline ground-water quality), the characteristics of the FBC waste (e.g., whole sample chemistry, leachability, porosity, permeability), and the proposed landfill design and operation parameters (e.g., area, depth or thickness, size of individual cells, wetting procedures, compaction). The output of the model may take one or more of several forms, such as the ground-water quality that may be expected at various distances from the proposed site as a function of time under different scenario disposal procedures that would be feasible at the site.

The conceptual model is being formulated by using the laboratory/field relationships established in this program, existing simulation models for ground-water flow, previous investigations of ground-water contaminant attenuation (using chromatographic theory, in part), and ongoing research efforts in flow/attenuation simulation model development for other waste types. Where necessary, original work will be accomplished in simulation model development to support the model formulation.

An ideal way of predicting the hydrologic effects of a particular proposed FBC waste disposal operation would be to collect certain key site-specific and waste-specific data which could then be input to a simulation model. Such models are performed, for example, for pollutant loading of streams, lakes, estuaries, and the ocean.

If a parallel model existed for pollutant loading of ground-water systems by FBC solid wastes, then the effects of several alternative waste disposal operations for a particular FBC plant could be predicted and the ones that are most environmentally acceptable could be selected for actual use. However, such a simulation model that is practicable and widely applicable does not yet exist. In the absence of this model, an attempt will be made in this task to accomplish the following:

- utilize the rigorous correlation between the results of laboratory and field studies that is being attempted in this program;

- conduct studies for formulation of a coupled flow/attenuation model that could be used, in combination with laboratory studies, to predict the water-quality impacts of disposal of FBC solid wastes;

- make use of previous and ongoing research efforts for development of flow/attenuation models for other types of wastes; and

- utilize other types of methodologies that have been developed for pre-disposal data acquisition, disposal site preparation, operational and post-operational monitoring, and shutdown of waste disposal sites.

Development of the conceptual model was initiated during the first year, but the bulk of the work remains to be accomplished.

SECTION 3

PHYSICAL CHARACTERISTICS OF FBC WASTES AND DISPOSAL MEDIA

Several types of analysis of the physical properties of FBC wastes and of the disposal media are being performed as part of this program. During future interpretive efforts of the study, these results will be used to support the interpretation of the chemical behavior of the wastes and disposal media.

PHYSICAL CHARACTERIZATION OF FBC WASTES

Physical characterization studies of the FBC wastes have included powder X-ray diffraction, particle size analysis, specific surface area determination, specific gravity measurement, and analysis by scanning electron microscope and electron microprobe analysis. During the first year, X-ray diffraction analysis has been conducted on FBC wastes from the small test unit at IERL-RTP and on PFBC wastes from the Exxon Miniplant. Other tests of physical characteristics have been performed only on the PFBC wastes.

Preliminary X-ray Analysis of IERL-RTP Wastes

Preliminary polycrystalline X-ray powder diffraction studies were carried out on waste samples from the IERL-RTP FBC unit. For that phase of investigation, X-ray data from the primary cyclone and bed draw samples obtained at two different temperatures from the FBC unit (1550° and 1930°F) were analyzed. These data indicate that additional heating had very little effect on the bed draw samples from the RTP unit, whereas there was a pronounced effect on the crystallinity of the fly ash sample collected from the primary cyclone. In the fly ash samples, the calcium sulfate and calcium oxide phases are apparently unaffected by changing bed temperature from 1550°F to 1930°F. However, the $CaCO_3$, Fe_3O_4, α-SiO_2, α-Fe_2O_3, $Ca(OH)_2$ peaks identified in the 1550°F sample were either completely absent in the 1930°F sample or were much lower in intensity, indicating less crystallinity.

X-ray Analysis of Exxon Miniplant PFBC Waste

X-ray powder diffraction of components found in the Exxon Miniplant PFBC waste has been completed. The materials from two runs of Cyclone #2 (runs 79 and 80) are composed of major quantities of anhydrite ($CaSO_4$) and α-quartz (α-SiO). These samples also contain some α-hematite (α-Fe_2O_3) and magnetite (Fe_3O_4). Dolomite [$CaMg(CO_3)_2$] and β-calcium silicate (β-$CaSiO_3$) are also present, and possibly $CaSO_4 \cdot 3MgSO_4$; unequivocable identification of $CaSO_4 \cdot 3MgSO_4$ is difficult in these particular samples due to the complexity of the pattern.

The major components in runs 80 and 81 of Cyclone #3 are α-quartz, $CaSO_4$ (anhydrite), and β-$CaSiO_3$ (β-calcium silicate). $CaSO_4 \cdot 3MgSO_4$, α-Fe_2O_3, and Fe_3O_4 are also present. Dolomite [$CaMg(CO_3)_2$], is also identifiable.

The mixed waste containing two parts bed draw, one part Cyclone #2, and 0.1 part Cyclone #3 is composed primarily of $CaSO_4$ and α-quartz. α-Fe_2O_3, Fe_3O_4, and dolomite are present too. Trace amounts of β-$CaSiO_3$, and possibly $CaSO_4 \cdot 3MgSO_4$ are identifiable.

Particle Size, Specific Surface Area, and Specific Gravity Determinations of PFBC Wastes

Analysis of the average particle size for mixed PFBC waste has been performed on samples that have been ground to the same extent as the samples used for the sequential batch leaching protocol. This particle size information should aid in interpretation of surface reactions in the laboratory studies. In order to determine the particle size, it is necessary to wet sieve the PFBC waste through a 104 micron sieve prior to analysis on a Sedigraph particle size analyzer. Therefore, the results of this test reflect only the particle size distribution of particles smaller than 104 microns. In a representative PFBC sample, 57.2 percent of the particles used in the laboratory protocol are larger than 104 microns. Of the remaining 42.8 percent, the average particle size has been determined to be 14.5 μm. For the PFBC waste (average particle size - 14.5 μm), the specific surface area is 0.9 m^2/g. The specific gravity has been determined to be 2.936 g/cc for the PFBC waste and the specific surface area is 0.9 m^2/g. Future studies will include grain size determination of the size fraction greater than 104 microns.

Scanning Electron Microscopic and Electron Microprobe Analysis

Scanning electron photo-micrographs have been taken of the PFBC waste at several magnifications. The micrographs will be utilized more fully at the end of this investigation.

The electron microprobe analysis has defined the elemental composition of two near-surface layers as follows: magnesium, aluminum, silicon, sulfur, potassium, calcium, and iron. Concentrations of a given element at different layer depths have been obtained for the original PFBC waste before leaching. This phase of investigation has been designed for later comparison with electron microprobe analysis of leached waste at different layer depths to determine surface-specific elements. Preliminary studies indicate qualitatively that all elements present appear to have similar concentrations in the surface layers except iron. More iron appears to be present on the interior layers rather than on the exterior layers. This difference may be indicative of the ease of removal of surface iron supportable by leaching data.

PHYSICAL CHARACTERIZATION OF DISPOSAL MEDIA

The physical characteristics determined for the disposal media are generally the same as were analyzed for the waste materials.

X-ray Analysis of the Disposal Media

X-ray powder diffraction has been carried out on the six disposal media to determine the mienrals present. This information aids in interpretation of the interactions between PFBC waste leachates with the media. The compounds enumerated in the interpretation of these data have been identified from diffraction patterns produced from ground specimens of whole samples from a representative portion of a medium segregated by the standard method of coning and quartering. This analysis provides an overall view of the crystalline compounds present in each medium. However, because these soil-like materials are natural composites, X-ray pattern complexity precludes unquestionable identification of all mineral fractions.

The readily identifiable crystalline components of the Greer limestone and glacial till are α-quartz (α-SiO_2), calcite ($CaCO_3$), and dolomite [$CaMg(CO_3)_2$]. From the whole sample analysis, several mineral components in the Greer limestone sample and the glacial till sample can be tentatively identified. Barium muscovite, phlogopite, and trioctahedral illite may possibly be present in trace amounts, based on observed patterns that are compatible with the interplanar d-spacings; however, further analysis is necessary to confirm the presence of these minerals.

The alluvium sample contains α-quartz as a major component and has d-spacings that are compatible with muscovite and albite.

Polycrystalline X-ray powder diffraction patterns of the shale, sandstone, and interburden samples produce similar complex diffraction patterns. The same components appear to be present in slightly different quantities in the three rock types. The major crystalline component in the shale, sandstone, and interburden is α-quartz. Diffraction peaks are also present that may possibly be compatible with chlorite, diopside, enstatite, augite, vermiculite, nontronite, phlogopite, muscovite, kaolinite, illite, montmorillonite; however, further analyses of the clay fraction from these whole samples is necessary to better specify individual clay mineral components. It is unlikely that all of these minerals are present.

Particle Size, Specific Surface Area, and Specific Gravity Determinations of the Disposal Media

Alluvium, interburden, shale, till, sandstone, and limestone samples were analyzed for average particle size after the samples were ground to the same extent as was done for the sequential batch leaching protocol. The interburden and alluvium samples contained particles too large for size analysis by the Sedigraph Particle Size Analyzer. This indicates that a large fraction of these two samples was composed of particles larger than 104 μm. The results of the average particle size analysis for the other media are given with other physical parameters in Table 15. The medium having the smallest average particle size, thus providing the largest surface area for reaction, is glacial till. The interburden, alluvium, and shale samples display larger surface areas for interaction than the sandstone and limestone samples. Future studies will include grain size determination of the size fraction greater than 104 microns.

The specific gravity measurements on the disposal media are also shown in Table 15. The shale, sandstone, glacial till, alluvium, and limestone have very similar densities. The mine interburden is somewhat less dense.

Cation Exchange Capacities of the Disposal Media

The cation exchange capacities of the disposal media are shown in Table 15. The sample exhibiting the greatest ability to exchange sodium ions is mine interburden. The other five media have approximately equal cation exchange capacities.

LINER COMPATABILITY STUDIES

Although no data have been collected from the liner studies, initial preparations have been made so that this phase of investigation can be initiated.

TABLE 15. PHYSICAL PROPERTIES OF DISPOSAL MEDIA

Sample Identification	Average Particle Size[1] (μm)	Specific Surface Area[2] (m^2/g)	Specific Gravity[3] (g/cc)	Cation Exchange Capacity[4] (me/100 g)
Shale	7.4	15.6	2.716	36.1
Sandstone	8.2	8.2	2.749	31.4
Alluvium	ND[5]	10.4	2.762	37.0
Glacial Till	3.2	23.8	2.766	35.6
Limestone	3.6	5.5	2.812	30.0
Mine Interburden	ND[5]	17.1	2.253	50.5

[1] The average particle size is given in terms of the average estimated spherical diameter of the particles. These determinations were performed by Micromeritics Instrument Corporation on a Sedigraph Particle Size Analyzer which uses low energy X-rays to measure concentration at decreasing sedimentation depths with increasing time. Only the fraction less than 104 microns is included. Future studies will include the remainder of the sample.

[2] The specific surface area has been determined by the Micromeritics Instrument Corporation using a modified B.E.T. method and nitrogen as the adsorbate.

[3] The specific gravity has been determined by the Micromeritics Instrument Corporation on an autopycnometer using an interactive technique of volume comparison and helium for the gas.

[4] The cation exchange capacity has been determined using a method of sodium saturation. These results are reported in milliequivalents per 100 g.

[5] Alluvium and mine interburden particles were too large for particle size analysis on the Sedigraph Particle Size Analyzer.

SECTION 4

LEACHATE GENERATION AND ATTENUATION RESULTS

This section presents the preliminary results of studies of the generation of FBC waste leachate as well as the results of the contaminant attenuation* characteristics of the disposal media when exposed to the FBC leachate. Results are given for both the laboratory and the field parts of the investigation. Also presented is a preliminary analysis of the possible correlation of laboratory and field leachate generation and attenuation results. All investigations thus far have been conducted with PFBC wastes only; AFBC wastes are projected for analysis during future program efforts.

The results presented in this section will be utilized to achieve parts of both of the major objectives of this program. Determination of the chemical characteristics of the waste leachates before and after exposure to the disposal media is an essential component of the overall aim of characterizing representative FBC residues and their interaction with natural media. The attempt to establish an empirical but reliable correlation of laboratory and field results is a key part of the development of an overall methodology for providing environmental protection from the impacts of FBC residues on a case-by-case basis.

The chemical analytical data for the laboratory and field studies are presented in Appendix I. Most of the summary data plots of this section were derived by use of the SAS data management system.

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*The term "attenuation" implies that contaminants are removed from leachate upon exposure to the disposal medium. In point of fact, as discussed below, the concentration of some constituents may increase in the leachate after exposure to the disposal medium (contaminant mobilization). Nevertheless, for the sake of simplicity, the term "attenuation" is used here to describe both true attenuation and mobilization.

The first part of this section describes results of the laboratory studies of leachate generation from PFBC wastes and of leachate interaction ("attenuation") with the six candidate disposal media. The second part describes the physical performance (water balance) of the field cells and the results of field studies of leachate generation and attenuation. The next part of the section contains a comparison of the attenuation behavior of the different disposal media. The final part of this section is a discussion of the interim results in the context of scaling up from laboratory studies to the leachate production behavior of FBC wastes at landfill sites.

Of the 20 chemical parameters selected for analysis in this program, three have been selected for presentation in this section. The parameters chosen are as follows:

- Calcium (Ca),
- Boron (B), and
- Sulfate (SO_4).

These parameters were selected as representative of the chemical behavior observed in studies conducted thus far. Calcium and sulfate represent major chemical components of the waste. Boron is included due to its predictable leaching behavior in coal ash materials. The remaining chemical parameters are included in the comparison of the results of this study with water quality standards and criteria in Section 5.

RESULTS OF LABORATORY STUDIES

Laboratory studies include analyses of leachates produced from PFBC wastes (leachate generation stage) and of PFBC leachates after exposure to the disposal media (leachate attenuation stage).

Leachate Generation

As noted in Section 2, leachates from a landfill disposal site are formed when infiltrating moisture contacts solid waste and is transported into the surrounding disposal media. In this experimental program, simulated leachates are generated, and the compositions of these leachates are quantified. Laboratory-generated leachates are obtained by batch equilibrations of CO_2-saturated deionized water with the PFBC solid waste (Protocol Steps 1 and 2), and batch equilibrations of previously generated leachate with additional fresh solid waste (Steps 1 and 3).

Data from the laboratory protocol are presented in this section as data plots depicting leachate component concentrations, usually in milligrams per liter (mg/ℓ), as a function of the volume of moisture that contacts the solid waste mass. The leachate volume independent variable (abscissa value) is normalized by dividing the volumes by the mass of the waste leached, resulting in a volume-to-mass ratio in milliliters per gram (mℓ/g) for the abscissa values.

As noted in Section 2, Protocol Step 1 equilibrates 250 mℓ of water with 25 grams of waste, thus providing a leachate with a value of 10 milliliters of water per gram of waste on the abscissa of the figures. Step 2 starts with the solids leached once in Step 1 and equilibrates these solids with 250 mℓ of fresh water, thus yielding a leachate that corresponds to 20 mℓ of water that have contacted the waste per gram of waste. This procedure is repeated using the same solids and additional fresh water to get the sequential leachate concentrations for each repetition of Step 2.

Protocol Step 3 is the repetitive equilibration of the Step 1 leachate with 25 grams of fresh solids, such that the first repetition has resulted in the contact of 250 mℓ water with 50 grams of waste. The value on the abscissa is thus 5 mℓ/g. The second repetition results in an abscissa value of 3.33 mℓ/g. In the data plots for Steps 1 and 3, the abscissa value increases to the right, with the result that the Step 1 value is plotted at the right side of the plot, and successive repetition values progress from right to left on the plot.

The remainder of this section is a discussion, for the selected chemical parameters, of the laboratory results of the leachate generation part of the investigation. It is important to note that the scales of the ordinates (concentrations) vary for different chemical parameters.

Calcium--

The calcium concentrations generated in Protocol Steps 1 and 2 (Figure 14) indicate that calcium is a major species in the laboratory-generated PFBC leachates. In Steps 1 and 2, the general trend is one of decreasing calcium concentrations with increasing volume-to-mass ratios. The concentrations of calcium for Protocol Steps 1 and 2 ranged from 500 mg/ℓ up to 1,700 mg/ℓ. After generally decreasing, the calcium concentrations level off and appear to be gently increasing after a volume-to-mass ratio of 80 mℓ/g is reached.

The calcium concentrations in leachates from laboratory Protocol Steps 1 and 3 ranged from 1,700 mg/ℓ up to 1,800 mg/ℓ, with the concentration increasing initially then decreasing with increasing mass-to-volume ratios as seen in Figure 15.

Boron--

The laboratory-generated leachates of PFBC waste are characterized by a gradual decrease in boron concentration approaching instrumental detection limits after a volume-to-mass ratio of 60 mℓ/g for Protocol Steps 1 and 2 (Figure 16). The concentration of boron in these leachates ranged from 1.0 mg/ℓ up to 18 mg . With the exception of one apparently spurious data point, the concentrations form a smooth decreasing curve which levels out at a volume-to-mass ratio of 60 mℓ/g.

For leachates generated by laboratory Protocol Steps 1 and 3, the boron concentrations decrease smoothly from 27.5 mg/ℓ at 3.3 mℓ/g to 12.5 mg/ℓ at a volume-to-mass ratio of 10 mℓ/g (Figure 17). This is almost a linear decrease in boron concentration with increasing volume-to-mass ratios.

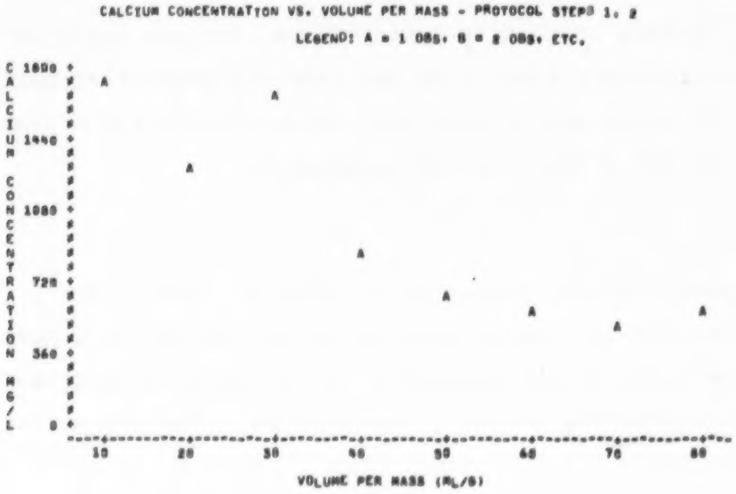
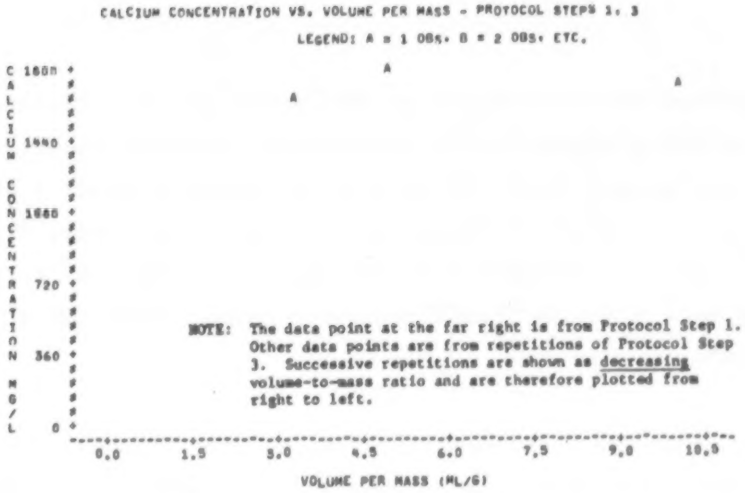


Figure 14. Laboratory Leachate Generation Data Protocol Steps 1 and 2 for Calcium



NOTE: The data point at the far right is from Protocol Step 1. Other data points are from repetitions of Protocol Step 3. Successive repetitions are shown as decreasing volume-to-mass ratio and are therefore plotted from right to left.

Figure 15. Laboratory Leachate Generation Data Steps 1 and 3 for Calcium

Sulfate--

The sulfate concentrations for leachates generated in Steps 1 and 2 increase from 1,225 mg/ℓ at a volume-to-mass ratio of 10 mℓ/g to a maximum of 1,450 mg/ℓ when the volume-to-mass increases to 55 mℓ/g (see Figure 18). After that point, the sulfate concentrations decrease rapidly to 1,050 mg/ℓ as the volume-to-mass ratio increases to 80 mℓ/g. These data exhibit no well-defined trend.

The sulfate concentrations for leachates generated in Protocol Steps 1 and 3 decrease with increasing volume-to-mass ratio, as shown in Figure 19. The concentration ranges from 1,230 mg/ℓ to 1,310 mg/ℓ, with concentration leveling off at higher volume-to-mass ratios.

Leachate Attenuation

Each of the six disposal media acquired for the program has been subjected to PFBC leachate in laboratory and field studies. This section presents attenuation data for the laboratory (batch equilibration) experiments.

As described in Section 2, each disposal medium is mixed for seven days with the Step 1, seven-day PFBC leachate in laboratory Protocol Step 4. The resulting "burdened" medium is contacted in repetitive steps with fresh Step 1 leachate (Protocol Step 5). Attenuation for each chemical parameter is defined by the following equation:

$$A_L = \frac{C_a - C_b}{C_a}$$

where

A_L = fractional attenuation (laboratory),

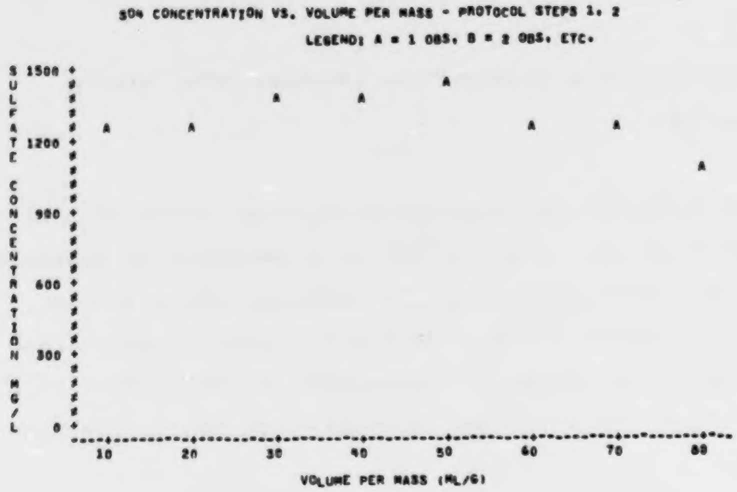
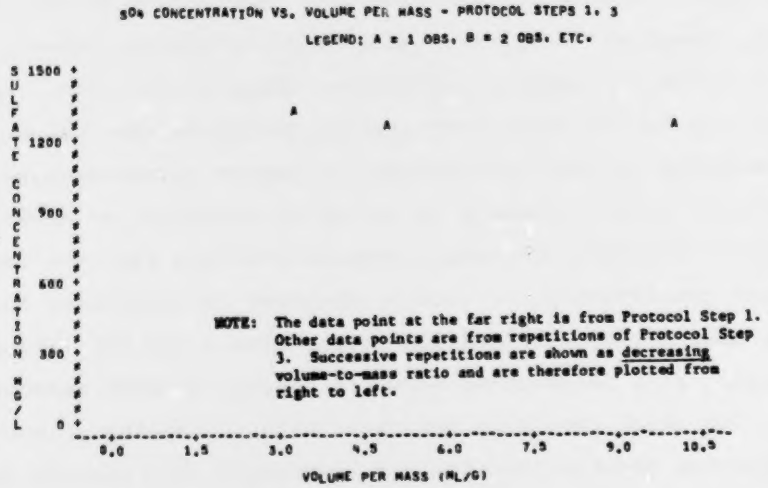


Figure 18. Laboratory Leachate Generation Data
Protocol Steps 1 and 2 for Sulfate



NOTE: The data point at the far right is from Protocol Step 1. Other data points are from repetitions of Protocol Step 3. Successive repetitions are shown as decreasing volume-to-mass ratio and are therefore plotted from right to left.

Figure 19. Laboratory Leachate Generation Data
Protocol Steps 1 and 3 for Sulfate

C_a = concentration of a parameter in Step 1 PFBC leachate, and

C_b = concentration of a parameter in leachate after mixing with medium.

Negative A_L values indicate contribution rather than attenuation of the parameter by the disposal medium. A definition of attenuation is possible for each of several repetitive contacts of the leachate with a medium. New batch extractions of the waste are required each seven days to ensure that the medium is contacted with fresh leachate. Reanalysis of the various batches of Step 1 leachate defines the component concentrations in the leachate prior to contact with media.

Laboratory studies consist of exposing a disposal medium with leachate equivalent to ten times the mass of the medium for each step. A total of five to seven repetitions has been performed for each medium to provide a volume-to-mass ratio of 10 to 70 mℓ/g.

Calcium--

As seen in Figure 20 showing leachate-shale interaction in the laboratory studies, calcium, though not completely attenuated initially, shows a linear increase in attenuation to complete attenuation after seven tests. Leachate-sandstone interaction in the laboratory studies indicates that calcium initially experiences moderate to poor attenuation; at higher volume-to-mass ratios, attenuation increases almost linearly to strong or complete, as shown in Figure 21. Leachate-alluvium laboratory results indicate that the calcium attenuation does not consistently increase or decrease in repetitive tests. At higher volume-to-mass ratios, the calcium attenuation drops off (Figure 22). The leachate-glacial till interaction shown in Figure 23 shows moderate attenuation of calcium which generally decreased with increasing volume-to-mass ratio. In interaction between leachate and limestone, the moderate attenuation fluctuates up and down as shown in Figure 24. The leachate-interburden interaction shown in Figure 25 shows increasing attenuation of calcium from initial moderate attenuation to complete attenuation at higher volume-to-mass ratios.

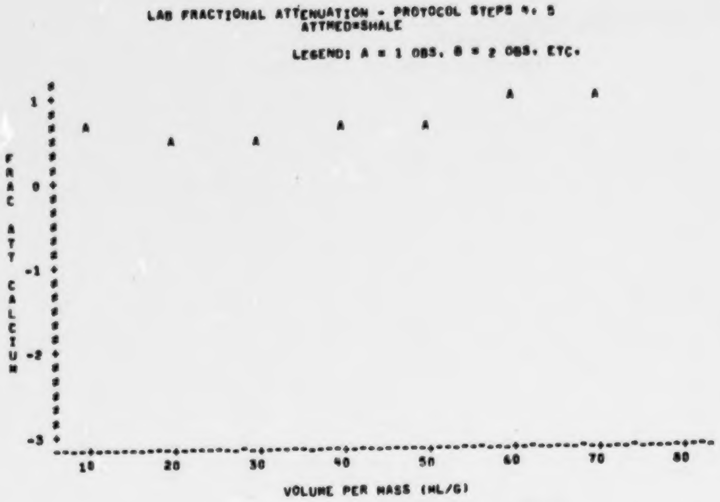


Figure 20. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Calcium by Shale

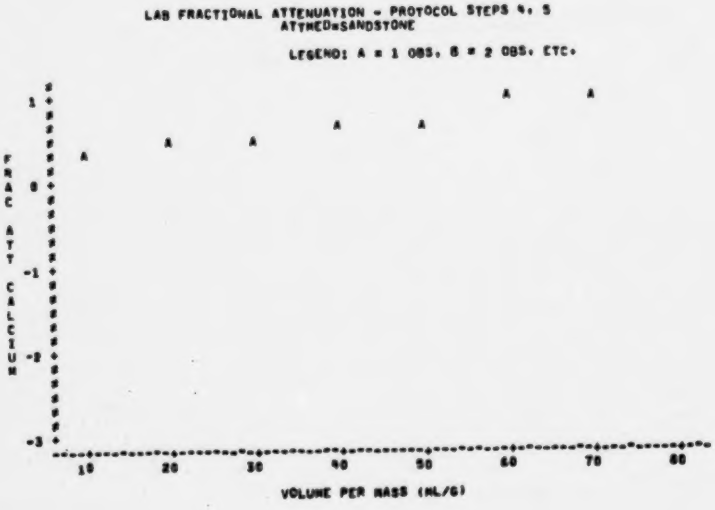


Figure 21. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Calcium by Sandstone

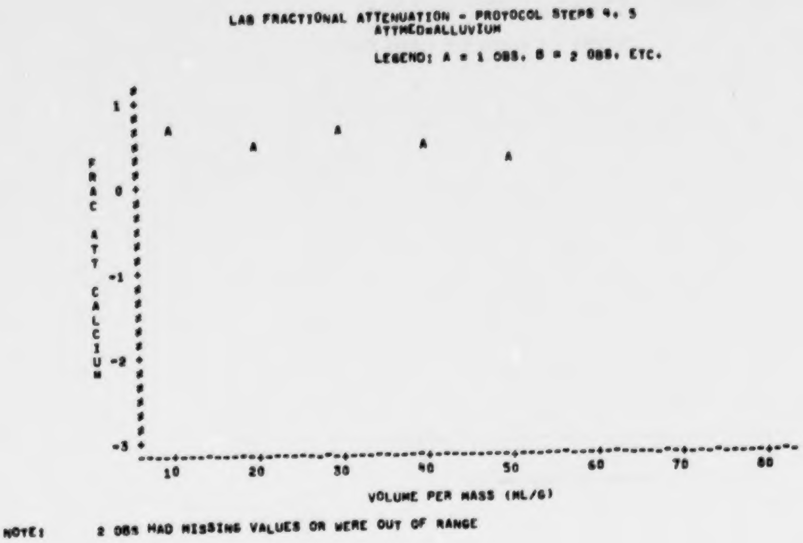


Figure 22. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Calcium by Alluvium

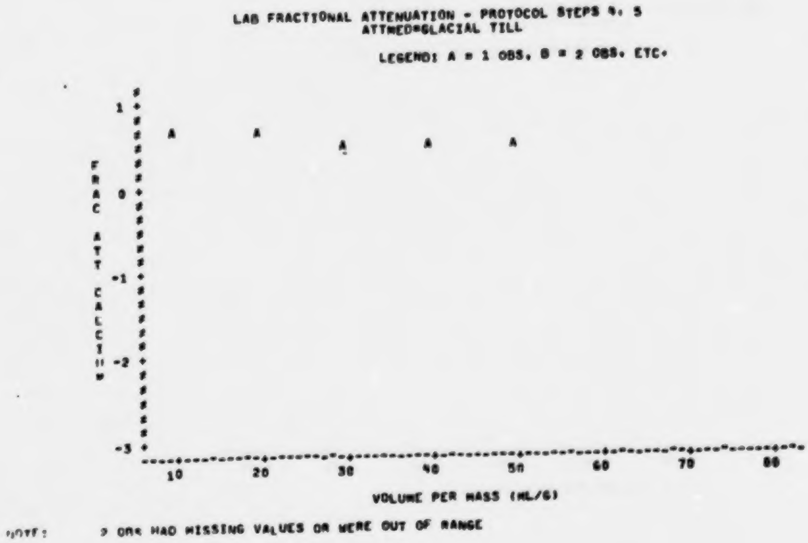


Figure 23. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Calcium by Glacial Till

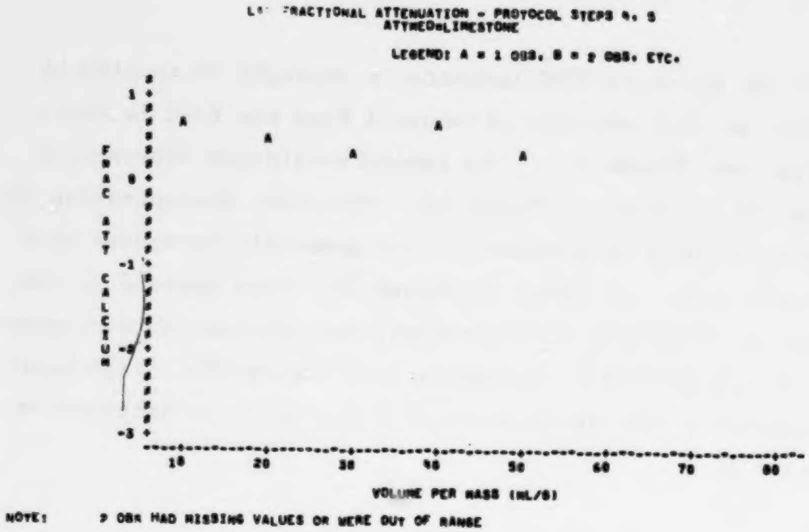


Figure 24. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Calcium by Limestone

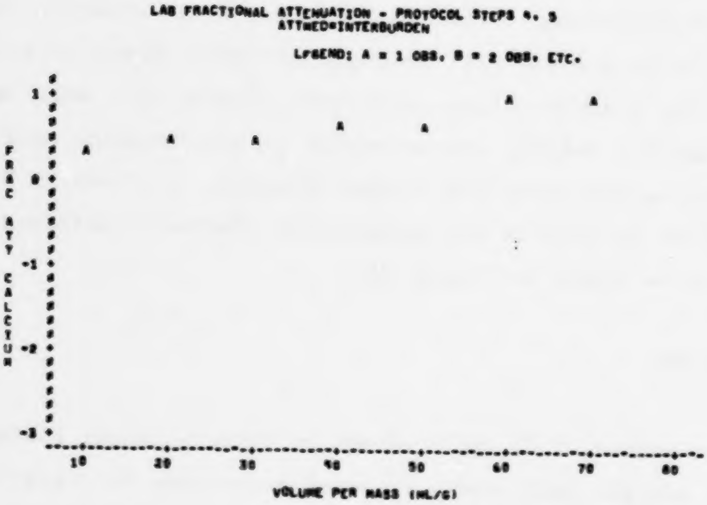


Figure 25. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Calcium by Interburden

Boron--

As seen in Figure 26, boron in PFBC leachate is strongly attenuated by the shale medium. Boron is also strongly attenuated from the PFBC leachate by the sandstone medium (see Figure 27). The leachate-alluvium interaction is one of high attenuation as shown in Figure 28. The boron concentration in leachate exposed to glacial till is attenuated, but generally decreases with increasing volume-to-mass ratio, as shown in Figure 29. When exposed to the limestone medium, boron is initially well retained, but attenuation decreases with further contact of leachate with the medium (see Figure 30). Laboratory results indicate consistently high attenuation of boron with the interburden medium as seen in Figure 31.

Sulfate--

The shale-leachate interaction showed initial partial sulfate attenuation, with a sharp decrease in attenuation by shale in subsequent tests as seen in Figure 32. Laboratory results indicate that sandstone-leachate contact results in moderate to poor attenuation of sulfate (see Figure 33). The attenuation of sulfate in alluvium-leachate interaction follows a generally constant attenuation trend with increasing volume-to-mass ratios, as shown in Figure 34. The sulfate attenuation in glacial till-leachate exposure decreases almost linearly with increasing mass-to-volume ratio (see Figure 35). When exposed to the limestone medium the sulfate concentration in the leachate exhibits rapid decrease in attenuation after the initial contact, as shown in Figure 36. Poor attenuation of sulfate by the interburden medium is observed in the laboratory studies as shown in Figure 37.

RESULTS OF FIELD STUDIES

Of the full test matrix of 17 cells shown on Table 4, eight field cells (Numbers 1 through 7 and 12) have been completed and placed in operation. These cells are shown on Table 16. Data are available for the first 90 days of observation (4 August 1979 through 1 November 1979) and are discussed in this section.

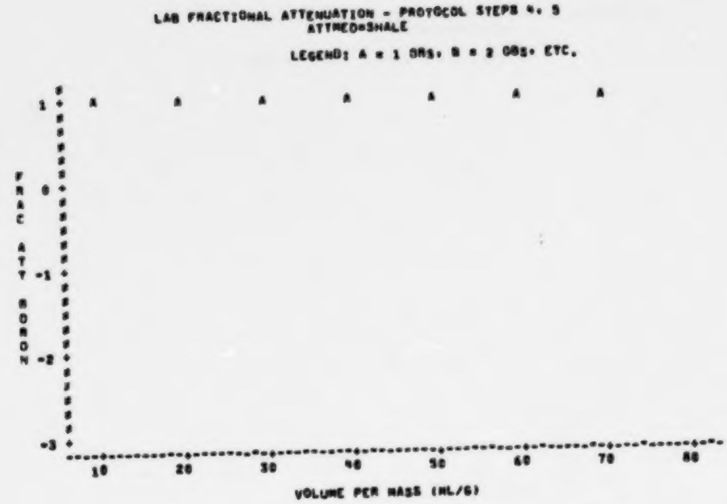


Figure 26. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Boron by Shale

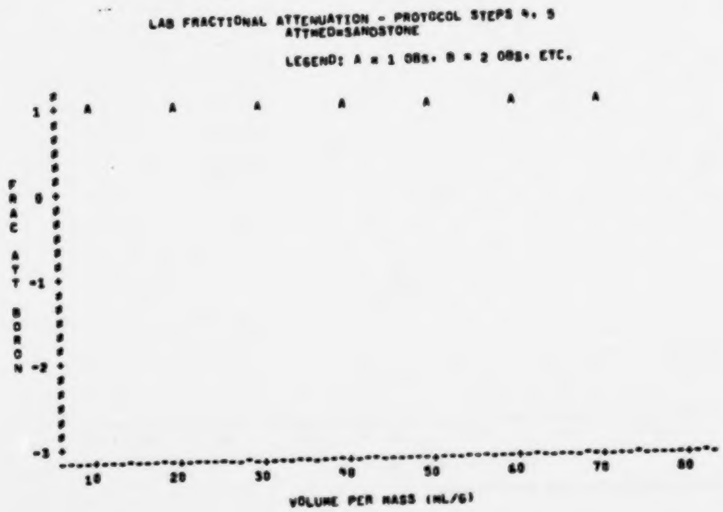


Figure 27. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Boron by Sandstone

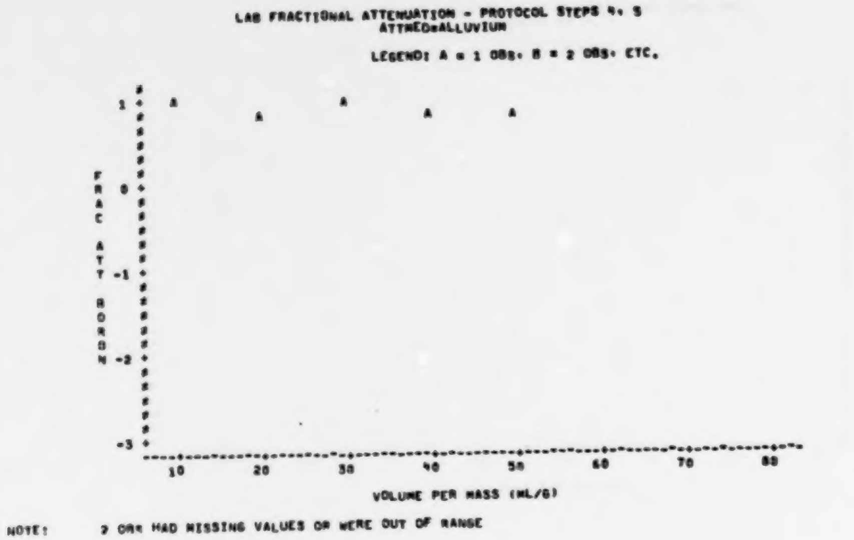


Figure 28. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Boron by Alluvium

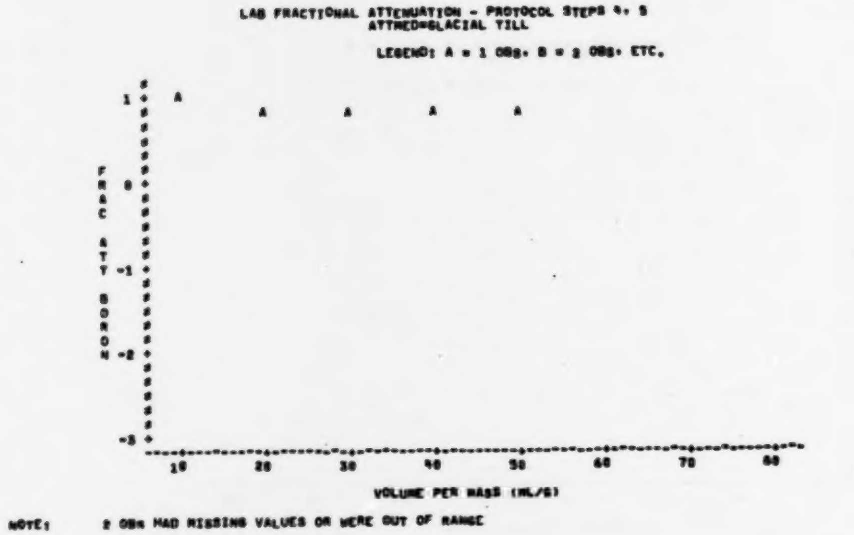


Figure 29. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Boron by Glacial Till

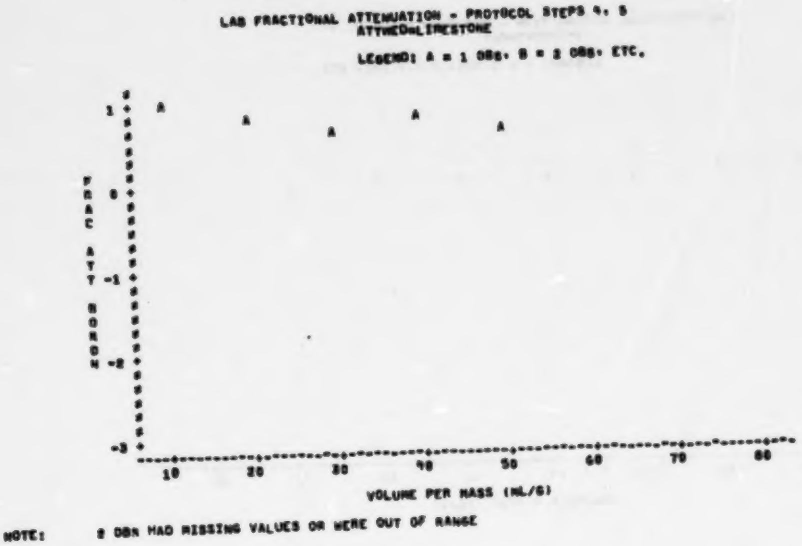


Figure 30. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Boron by Limestone

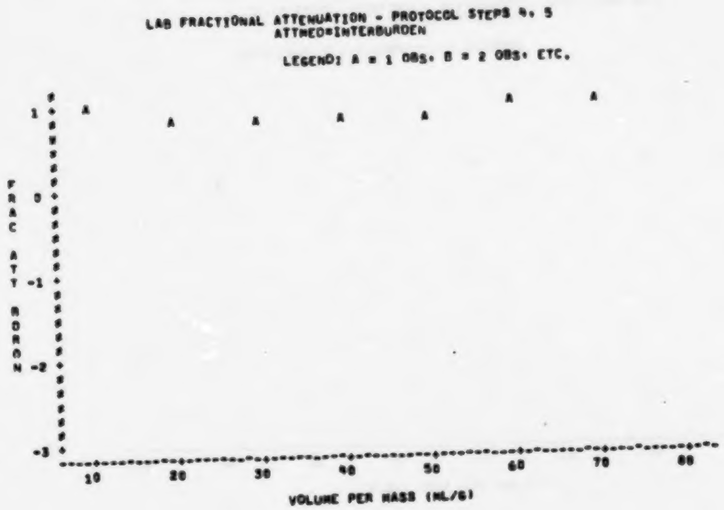


Figure 31. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Boron by Interburden

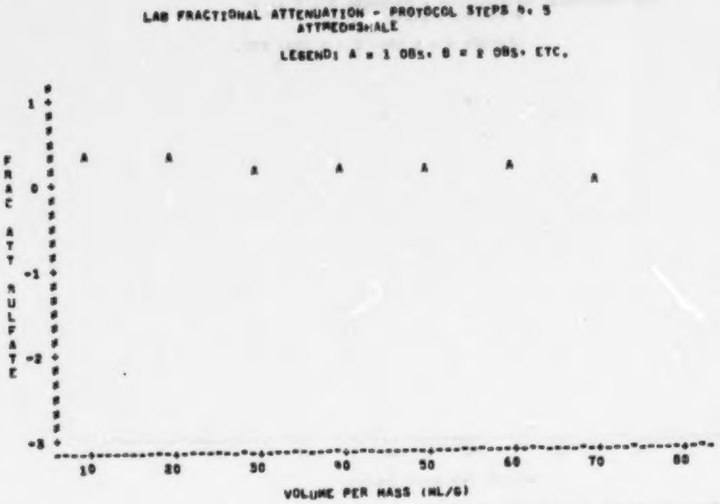


Figure 32. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Sulfate by Shale

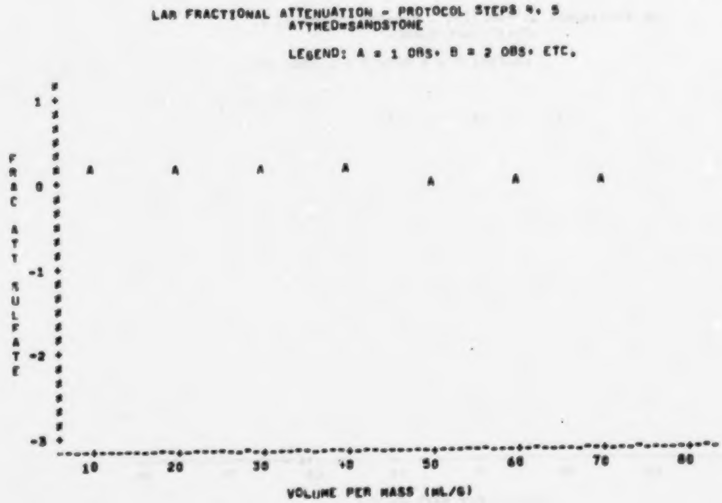


Figure 33. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Sulfate by Sandstone

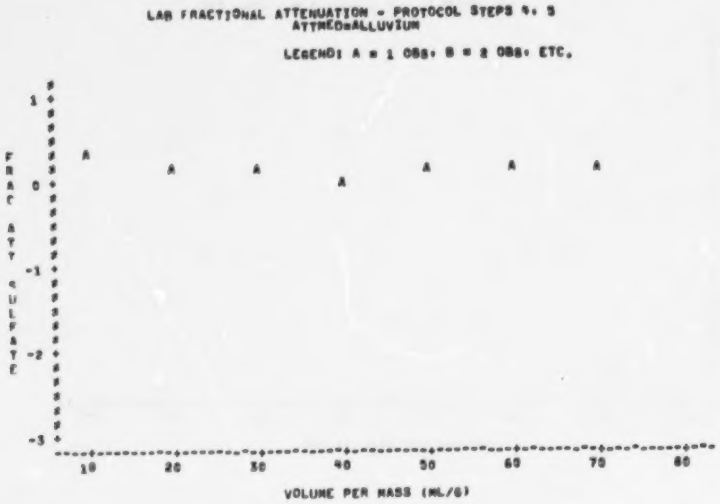


Figure 34. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Sulfate by Alluvium

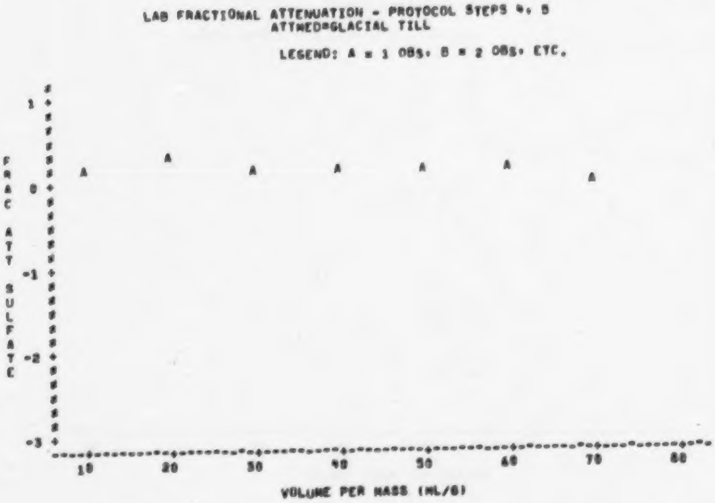


Figure 35. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Sulfate by Glacial Till

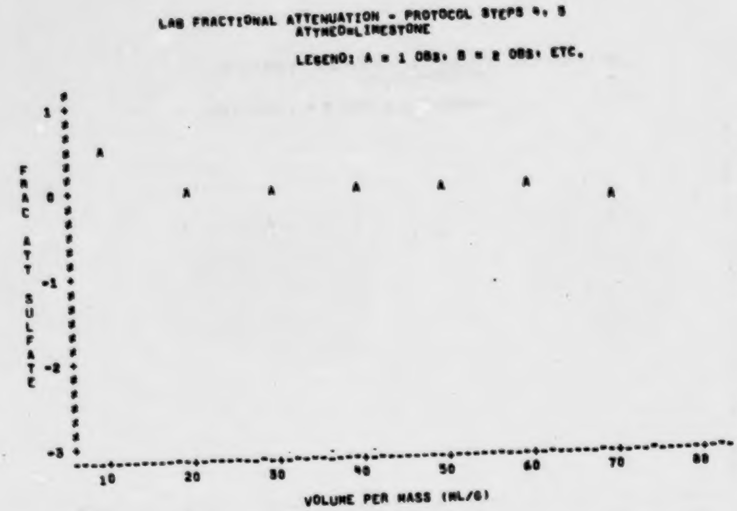


Figure 36. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Sulfate by Limestone

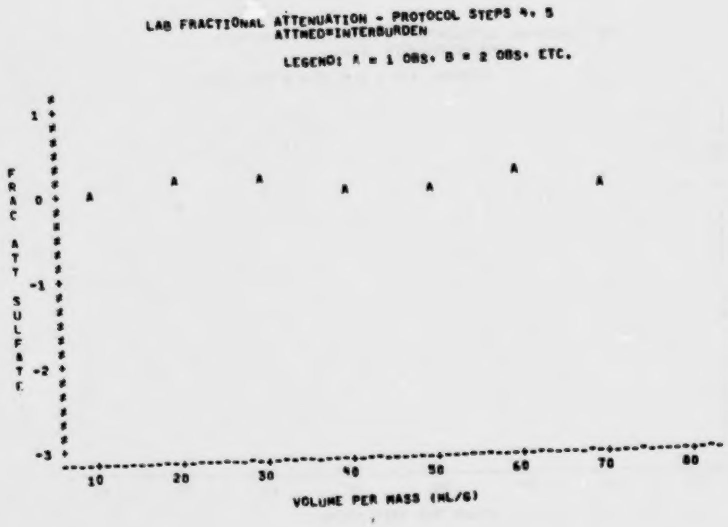


Figure 37. Laboratory Fractional Attenuation Data, Protocol Steps 4 and 5 for Attenuation of Sulfate by Interburden

TABLE 16. CONTENTS OF COMPLETED (OPERATING) FIELD CELLS

Cell Number	Medium	Mass of Medium x 10^6g	Waste	Mass of Waste x 10^6g
1	Shale	1.7	PFBC	0.8
2	Shale	1.7	PFBC	0.8
3	Till	1.2	PFBC	0.8
4	Limestone	1.8	PFBC	0.8
5	Alluvium	1.5	PFBC	0.8
6	Sandstone	1.8	PFBC	0.8
7	Shale	3.3	None (Control)	--
12	Alluvium	3.0	None (Control)	--

Average mass/cell = 2.6 x 10^6g

The available chemical data represent only a small initial part of the field cell sampling program. An average of 308 liters of moisture, equivalent to 264 mm of rain, have been removed from each field cell. This volume of water is much smaller (<1 mℓ/g) than the solid-to-liquid ratio observed in the laboratory. The 264 mm of throughput represents roughly one quarter of the expected annual precipitation input.

While the relatively dense early sampling schedule is intended to define the expected rapid changes in leachate composition, early observations are relevant only in the light of long-term observations. Patterns of change evident over short time frames may not be reflective of long-term behavior. The full range of possible relationships have not been explored at this time. Direct comparisons of laboratory and field data plots are therefore not valid at this point in the program.

Data for the laboratory control (media only) columns are not yet available. The initiation of operation of these columns was delayed to allow transcription of Crown rainfall records. Therefore, the only control data available are for the shale and alluvium control cells at Crown. Knowledge of the levels of constituents leached from the media by rainfall alone will be necessary for unambiguous interpretation of field cell data.

Field Cell Water Balance Analysis

The field cells have been exposed to a water input of 671 liters (575 mm depth), 296ℓ (254 mm) of initial irrigation applied as shown in Table 9 and 375ℓ (321 mm) of natural rainfall. The rainfall depths for each month are shown in Table 17, as is the total initial irrigation. Also shown are the corresponding monthly mean precipitation depths for Manningtown, West Virginia, from Table 5. A plot of cumulative volumes per cell of irrigation and rainfall at Crown is shown in Figure 38. Measureable precipitation occurred on 36 days. However, the line-printer format of Figure 38 only displays the three irrigation events and the 15 largest precipitation events.

TABLE 17. INITIAL IRRIGATION AND RAINFALL FOR FIELD CELLS AT CROWN, WEST VIRGINIA

Month	Depth of Rainfall (mm)	Equivalent Volume per Cell (liters)	Mean Precipitation at Mannington, West Virginia (mm)
Initial Irrigation	254	297	--
August	123	144	112
September	124	145	81
October	74	86	66
TOTALS	575	672	259

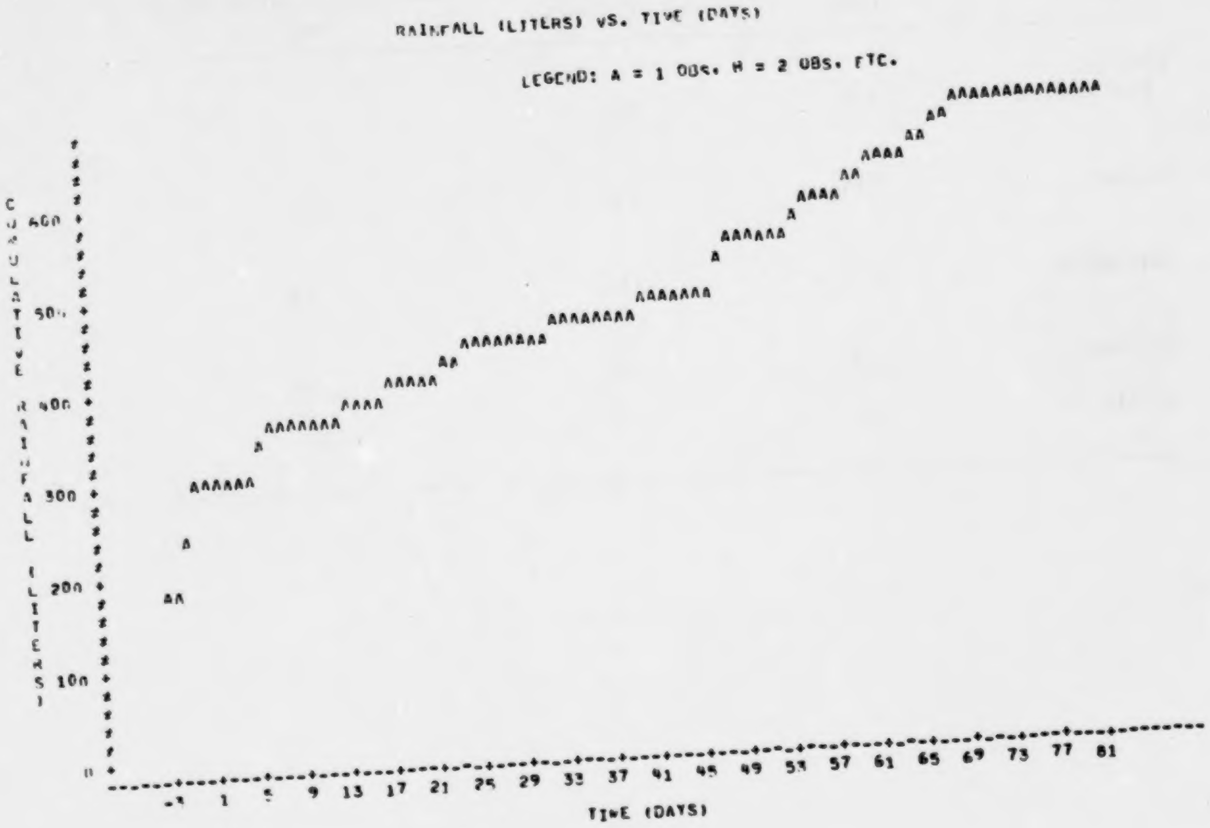


Figure 38. Rainfall Mass Curve, Cumulative Volume of Precipitation Per Cell

The total throughput (output) of the field cells is composed of the volumes withdrawn by the two sample arrays plus the volume removed by the bottom drain. The average volume removed is 308 liters per cell, which is equivalent to a water depth of 264 mm. Variation among cells is significant, ranging from a low of 226 liters to a maximum output of 378 liters. The pattern of cumulative average volume throughput over time is shown in Figure 39. Figure 40 is a double mass curve of rainfall per cell (abscissa) versus average throughput per cell (ordinate). It shows the relationship between cumulative input and output. The relationship is expected to be linear, and the data points of Figure 40 should approximate a straight line. The slope of the line will be one if there are no unmeasured losses from the cell. The intercept with the abscissa is a measure of storage within the sytem, as discussed below. Deviations from a straight-line relationship reveal non-linearities within the system, such as delayed drainage. That is, if there were no effect of delayed drainage, the double mass curve of Figure 40 would approach a straight line throughout its length. Large rainfall events not instantaneously reflected in throughput displace data points to the right, or below a line of best fit. As an example, consider the large rainfall event of days 6-8 on Figure 38. The outflow of these days (Figure 39) is not as large. Therefore, the corresponding data points of Figure 40 (300-360 liters along the abscissa) are displaced to the right.

Since media and wastes were emplaced dry, or nearly so, a portion of the irrigation input does not contribute to outflow, but instead satisfies the initial soil moisture storage requirements of the contents of each cell. The difference between total input and total output should be a measure of storage within the system. This relationship is somewhat obscured by the slow drainage of moisture through the cells, as may be seen by considering Figure 40. Sufficient data are not available to estimate reliably the field moisture capacity of each individual field cell. However, an average for all cells may be estimated in the following manner. An average of 363 liters (671 liters minus 308 liters) remained in storage in each cell at the end of the observation period. Since only 2 mm of rain had occurred during the preceeding 19 days, substantially all free water should have drained from the cells. Therefore, 363 liters is a reasonable trial estimate of the average field moisture

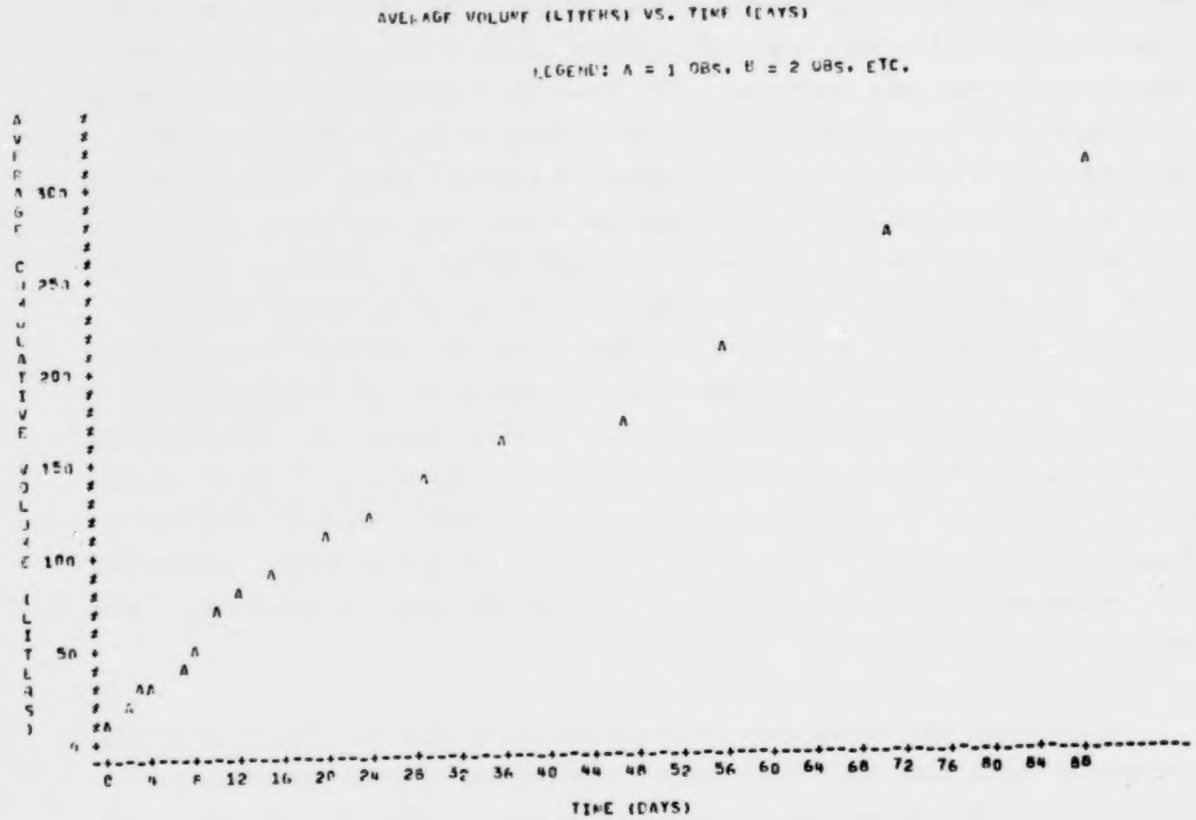


Figure 39. Throughput Mass Curve, Cumulative Volume Per Cell

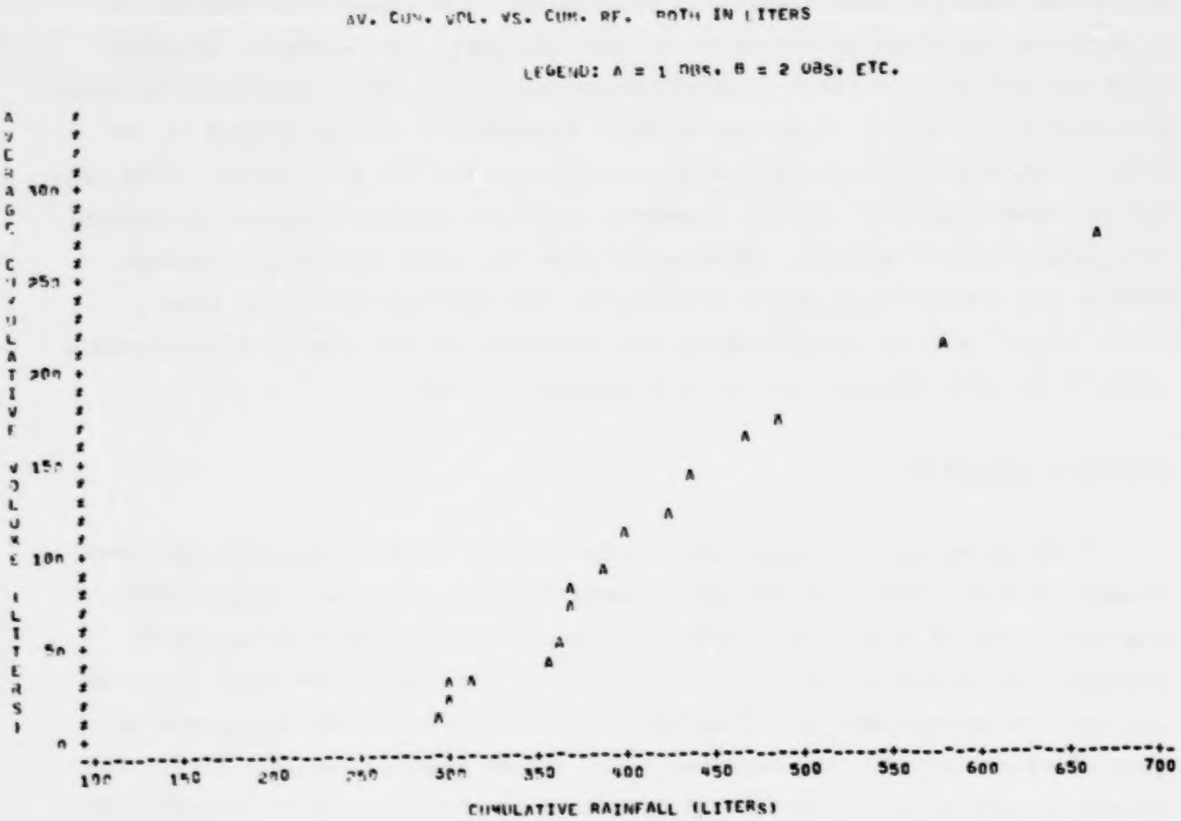


Figure 40. Double Mass Curve, Throughput vs. Rainfall

capacity of the cells. The field moisture capacity of each cell should fall in the neighborhood of this value. Once the cumulative throughput volume has been determined for several time frames closed by a rainless period, the field moisture capacity will be determined for each individual cell.

The preceeding considerations may be specious, inasmuch as losses from the system have not been explicitly considered. The field cells may not be as efficient rainfall receptors as is the rain gage. For example, the cell walls may deflect a portion of wind-driven rain, such that not all of the rainfall enters the cells. A series of small receptacles will be placed in the cells to measure cell rainfall catch to compare with the gage catch. This cannot be undertaken until spring, however, since the current dominant precipitation form at Crown is snow. Evaporation from the cell surface and leakage through the bottom liner are both possible, but are believed to be minor. Their effects will be quantified by consideration of the long term double-mass curve of rainfall versus cumulative throughput volume.

Leachate Generation

Field-generated leachates are obtained from a porous cup sampling array located directly under the FBC solid waste layer in the field cells (upper sampling point of Figure 7). Data for leachate generation from the field cells may be considered in a manner similar to the laboratory data; i.e., as leachate concentrations as a function of the moisture volume throughput per gram of waste (mℓ/g). Two important differences exist, however. First, the volume-to-mass scale for the field data is more than two orders of magnitude smaller than on the laboratory data scale. This is because the field cells receive all their moisture from natural rainfall, and the mass of FBC solid waste in the cells is fixed to provide a 1½ foot deep waste layer. The field cells will have to operate for more than five years to reach a moisture throughput equivalent to the Protocol Step 1 (10 mℓ/g). The second important difference is that five of the six field cells each contain a different disposal medium, and a one-foot layer of the disposal medium covers the waste in each cell. The infiltrating precipitation therefore contacts this media before the waste, such that the concentration determined for the field leachate generation are influenced by the attenuating media, as well as the FBC waste.

The remainder of this section is a discussion for the selected chemical parameters of the field results for the leachate generation part of the investigation.

Calcium--

The field experimental data for calcium are shown as plots of concentration versus volume-to-mass ratios in Figure 41.

The calcium concentrations for all the field cells have a maximum of 400-500 mg/ℓ between 0.12 and 0.2 mℓ/g throughput. The calcium concentration from cell No. 1 (containing shale) appears to increase rapidly between volume-to-mass ratios of 0.02 mℓ/g to 0.18 mℓ/g, at which point the concentration begins dropping (Figure 41a). The range of calcium concentrations for cell No. 2 (also containing shale) generally behaves like cell No. 1, except that there is more scatter in the experimental data (Figure 41b). The range of calcium concentrations for cell No. 2 is from 325 mg/ℓ to 500 mg/ℓ. The initial trend in the calcium concentrations is similar to cell No. 1 behavior in that the concentrations increase with increasing volume-to-mass ratios up to 0.21 mℓ/g.

Field cell No. 6 containing sandstone as the disposal medium, cell No. 5 containing alluvium, and cell No. 4 containing limestone show almost a linear increase in calcium concentration with increasing volume-to-mass ratio up to 0.15 mℓ/g (Figures 41c, d, f). After that point, the calcium concentration gradually decreases. In cell No. 3 containing glacial till, the increase in calcium concentration is more gradual, and the decrease in concentrations is barely beginning at the last data point thus far plotted (Figure 41e).

The values for calcium concentrations are much lower for field leachates than for laboratory leachates. The behavior for all field cells was generally similar and included maxima followed by a decrease in concentration. A summary of calcium concentrations and trends for field generated leachates is given in Table 18.

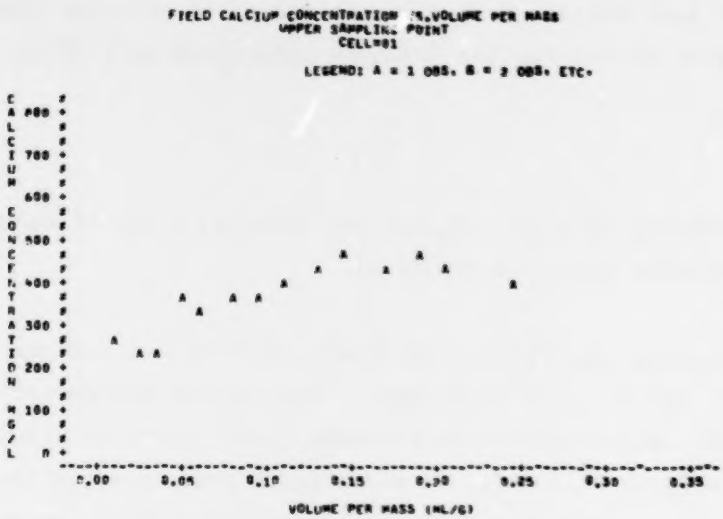


Figure 41a. Field Cell No. 1 (Shale).

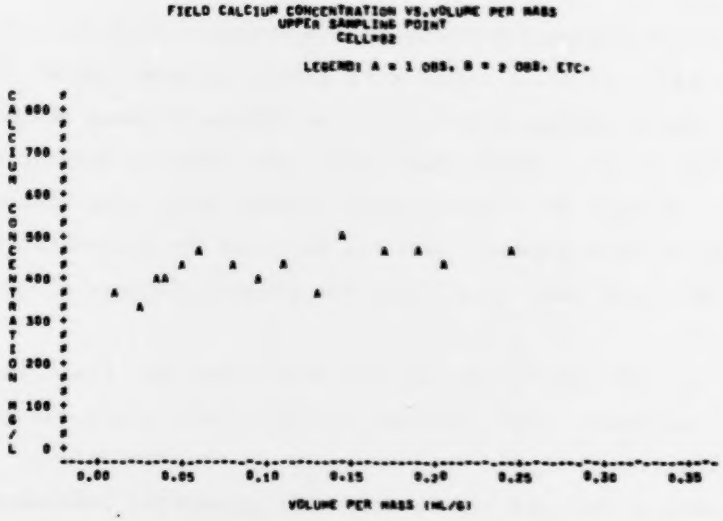


Figure 41b. Field Cell No. 2 (Shale).

Figure 41. Field Leachate Generation Data for Calcium.

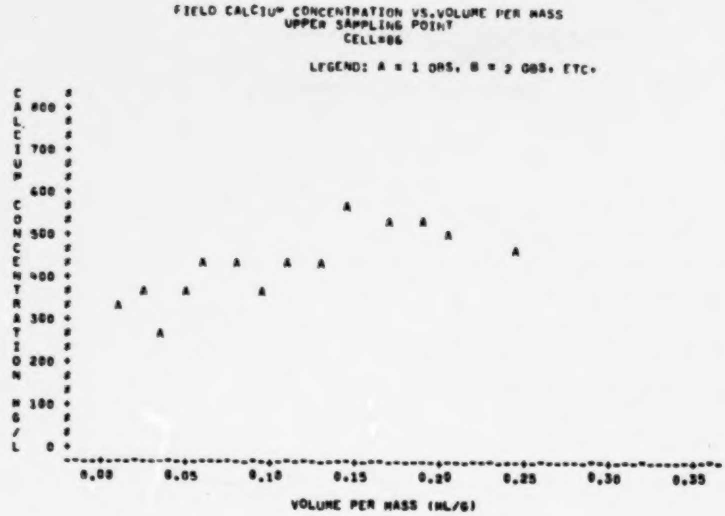


Figure 41c. Field Cell No. 6 (Sandstone).

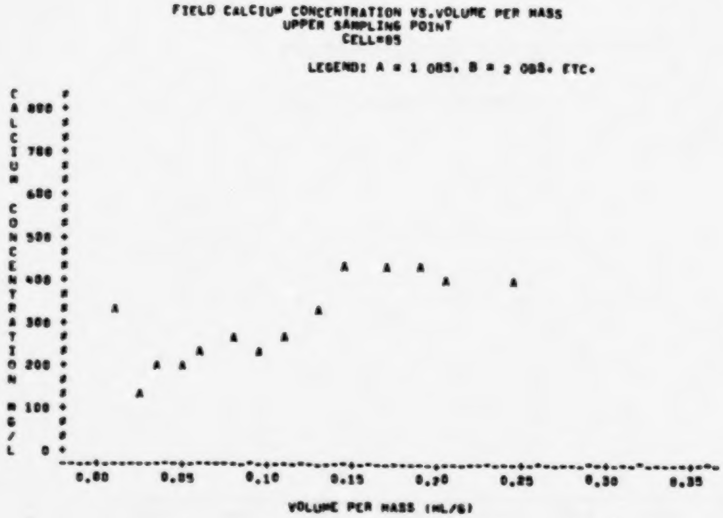


Figure 41d. Field Cell No. 5 (Alluvium).

Figure 41. Field Leachate Generation Data for Calcium (Continued).

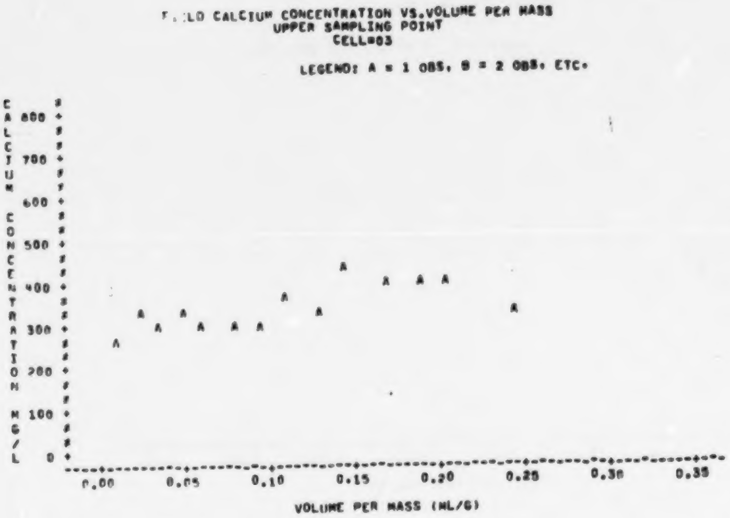


Figure 41e. Field Cell No. 3 (Glacial Till)

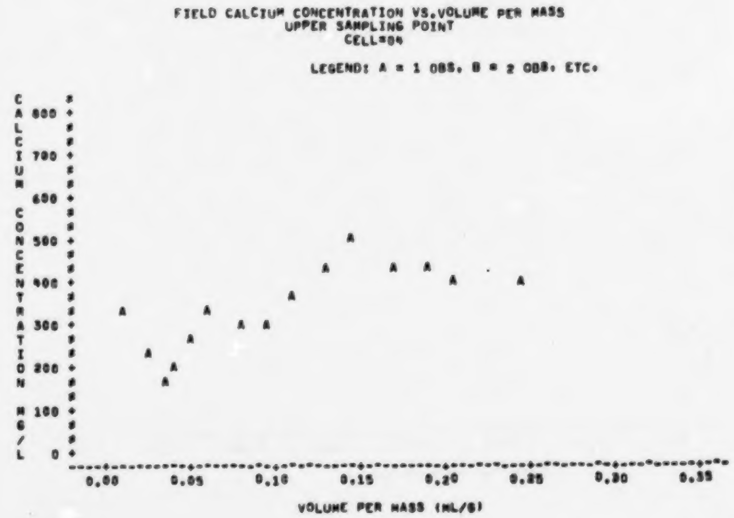


Figure 41f. Field Cell No. 4 (Limestone)

Figure 41. Field Leachate Generation Data for Calcium (Continued)

TABLE 18. FIELD LEACHATE GENERATION COMPARISON FOR CALCIUM

Generating Protocol	Concentration Range (mg/ℓ)	Concentration Trend*	Comments
Shale (Field Cell #1)	200-500	Increase	Concentration peaks at 0.15 mℓ/g, the begins gradually decreasing; values are considerably lower than lab.
Shale (Field Cell #2)	300-500	Increase	Although these data are more scattered than for cell #1, the trend is the same.
Sandstone (Field Cell #6)	250-600	Increase	Concentration peaks at 0.15 mℓ/g, then gently decreases; this behavior is consistent with cells #1 and #2.
Alluvium (Field Cell #5)	100-450	Increase	Behavior is consistent with above comments.
Glacial Till (Field Cell #3)	275-425	Increase	Consistent with above comments.
Limestone (Field Cell #4)	150-500	Increase	Consistent with above comments.

*With increasing volume-to-mass ratio.

Boron--

The field results for boron are shown in Figure 42.

For field cell No. 1 (shale) leachates, the boron concentration generally decreases from 25 mg/ℓ to 5 mg/ℓ at 0.24 mℓ/g (Figure 42a). The boron appears to continue to slowly leach from the solids as the volume-to-mass ratio increases. Field cell No. 2 leachates show the same general behavior (Figure 42b), but the data are somewhat more scattered. Field cell No. 6 (sandstone), No. 3 (till), and No. 4 (limestone) exhibit behavior very similar to field cell No. 1 (Figures 42c, e, f). This gradual decrease in boron concentration along with two small concentration peaks at volume-to-mass ratios of 0.1 mℓ/g and 0.18 mℓ/g, appears very consistent. Cell No. 5 leachates (Figure 42d exhibit less consistent behavior with a reduced concentration range (3 mg/ℓ). These data are also more scattered.

The behavior of boron in field leachates is probably the most consistent data exhibited insofar as predicted behavior is concerned. The decreasing trends are very consistent. This behavior may be indicative of a very soluble surface species that desorbs rather than a bulk species that is being dissolved. A summary of boron concentrations and trends for laboratory and field generated leachates is given in Table 19.

Sulfate--

The field data for sulfate are shown in Figure 43.

Initially the sulfate concentration at 0.01 mℓ/g volume-to-mass ratio is approximately 26,000 mg/ℓ for field cell No. 1 (Figure 43a). As the volume-to-mass ratio increases to 0.03 mℓ/g, the concentration decreases to 14,000 mg/ℓ and then levels off at about 5,000 mg/ℓ from a volume-to-mass ratio of 0.12 mℓ/g to 0.24 mℓ/g. Sulfate concentrations in leachates appears to drop slightly after this point. The trend in sulfate concentration for field cells No. 2 (shale) and No. 4 (limestone) are very similar to cell No. 1 behavior (Figures 43b and 43f).

For cell No. 6 (sandstone, Figure 43c), the sulfate concentrations are initially high 20,000 mg/ℓ at 0.02 mℓ/g). The concentration decreases to about 5,500 mg/ℓ where it remains relatively constant from 0.03 mℓ/g to 0.24 mℓ/g volume-to-mass ratio.

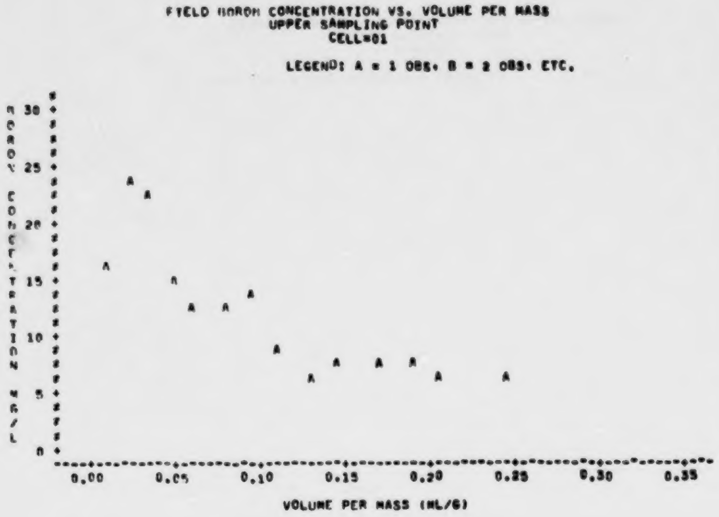


Figure 42a. Field Cell No. 1 (Shale)

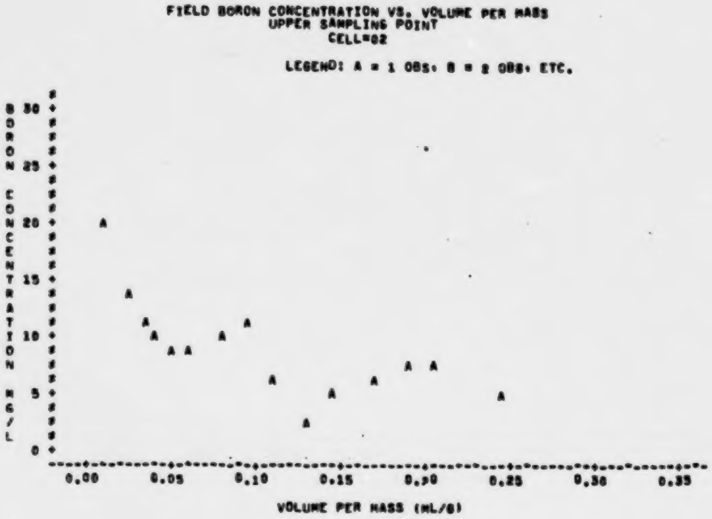


Figure 42b. Field Cell No. 2 (Shale)

Figure 42. Field Leachate Generation Data for Boron

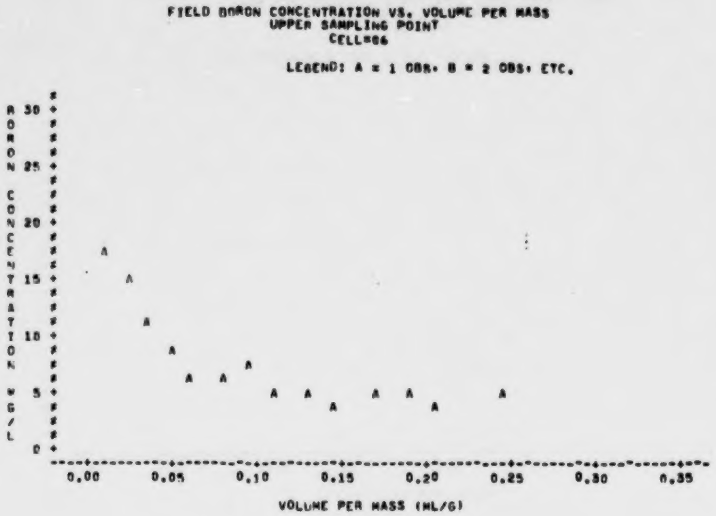


Figure 42c. Field Cell No. 6 (Sandstone).

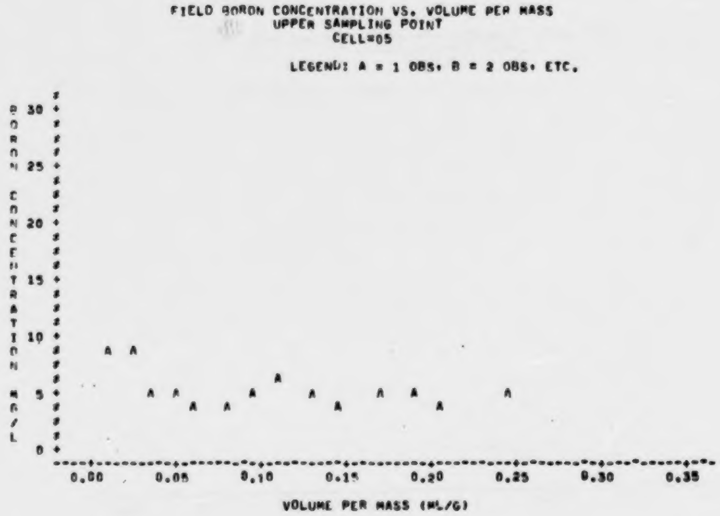


Figure 42d. Field Cell No. 5 (Alluvium).

Figure 42. Field Leachate Generation Data for Boron (Continued).

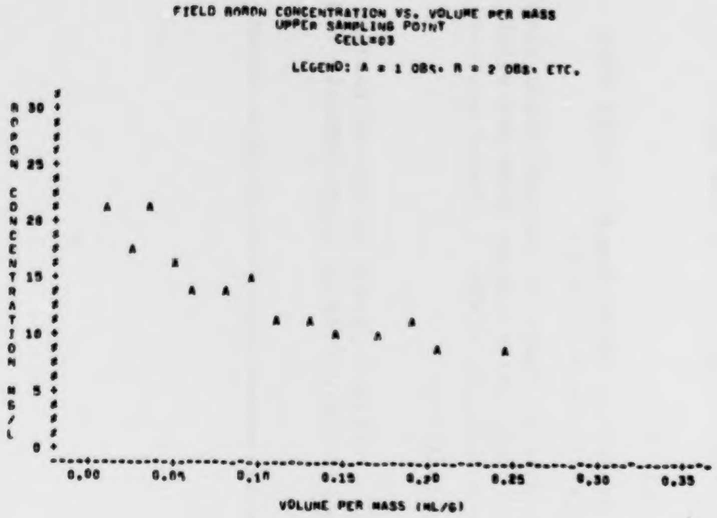


Figure 42e. Field Cell No. 3 (Glacial Till).

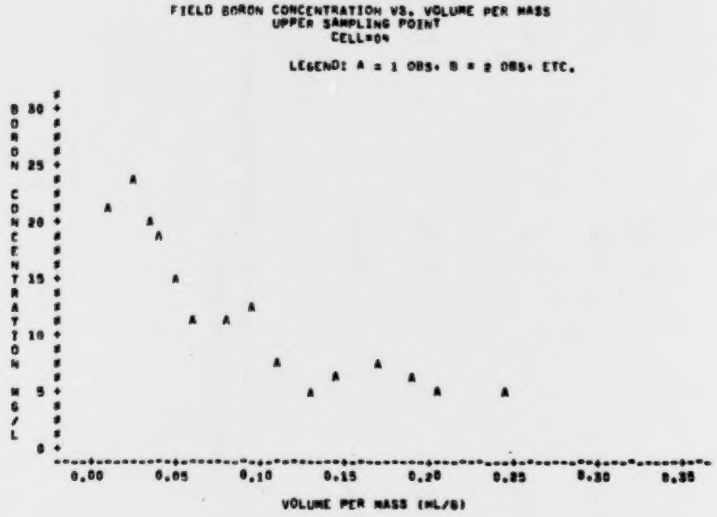


Figure 42f. Field Cell No. 4 (Limestone).

Figure 42. Field Leachate Generation Data for Boron (Continued).

TABLE 18. FIELD LEACHATE GENERATION COMPARISON FOR BORON

Generating Protocol	Concentration Range (mg/ℓ)	Concentration Trend*	Comments
Shale (Field Cell #1)	5-25	Decrease	A rapid decrease in B concentration followed by a constant low level after 0.12 mℓ/g is observed. Trend similar to lab.
Shale (Field Cell #2)	2.5-20	Decrease	Same as above.
Sandstone (Field Cell #6)	2-18	Decrease	Concentration decreases initially then levels off at 0.12 mℓ/g.
Alluvium (Field Cell #5)	3-8	Decrease	Much smaller range of concentration than other field cells; these data are slightly more scattered; almost a linear decrease.
Glacial Till (Field Cell #3)	8-25	Decease	Same as above.
Limestone (Field Cell #4)	5-25	Decrease	After a rapid decrease in concentration, values level off after approximately 0.12 mℓ/g.

*With increasing volume-to-mass ratio.

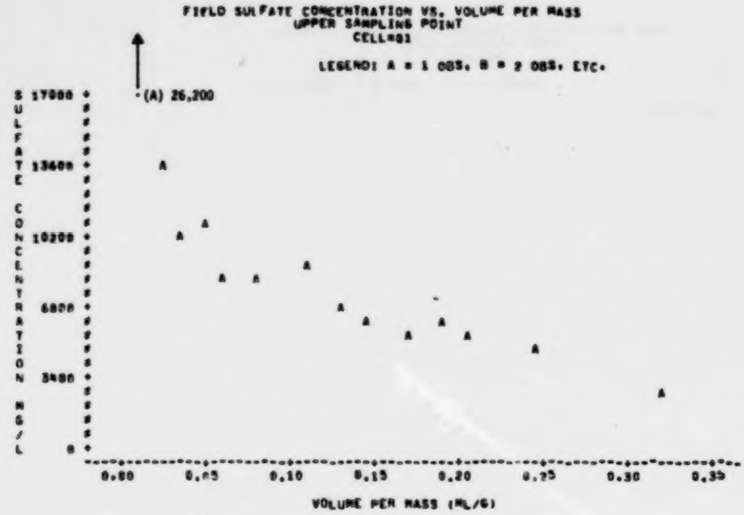


Figure 43a. Field Cell No. 1 (Shale).

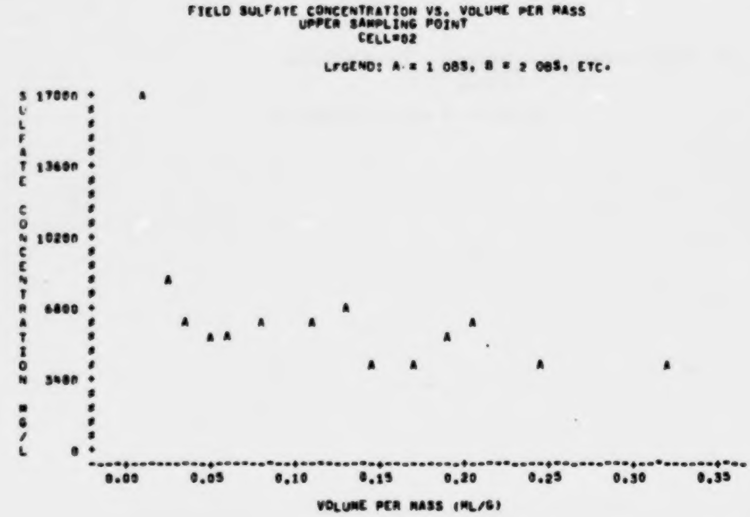


Figure 43b. Field Cell No. 2 (Shale).

Figure 43. Field Leachate Generation Data for Sulfate.

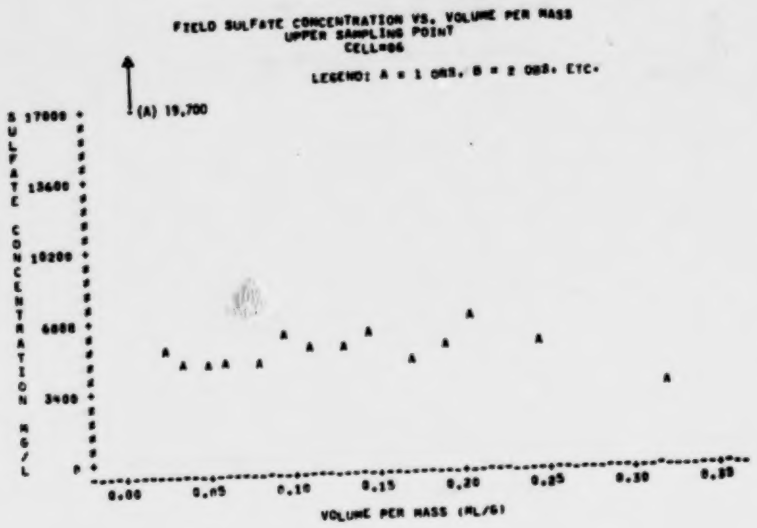


Figure 43c. Field Cell No. 6 (Sandstone).

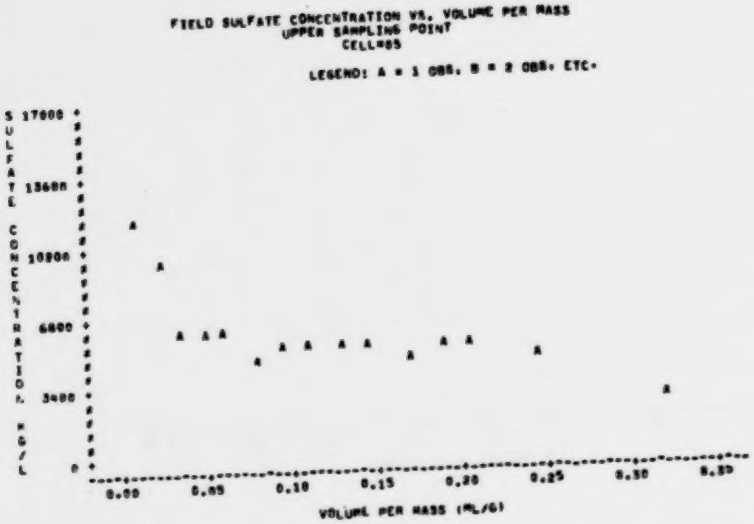


Figure 43d. Field Cell No. 5 (Alluvium).

Figure 43. Field Leachate Generation Data for Sulfate (Continued).

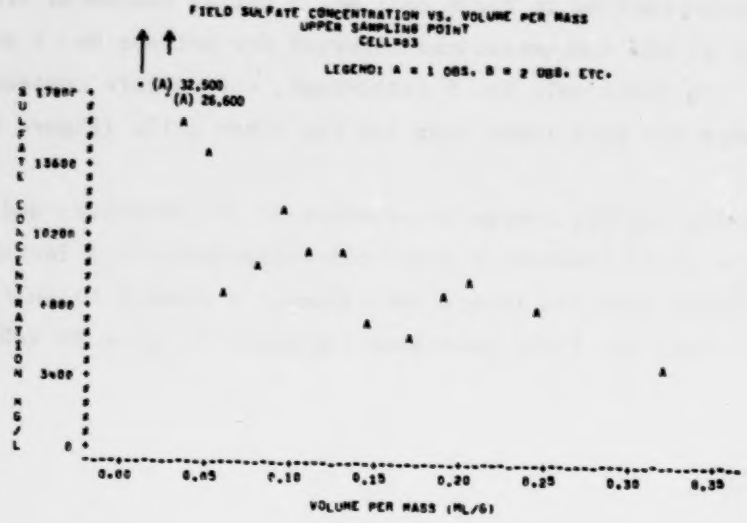


Figure 43e. Field Cell No. 3 (Glacial Till).

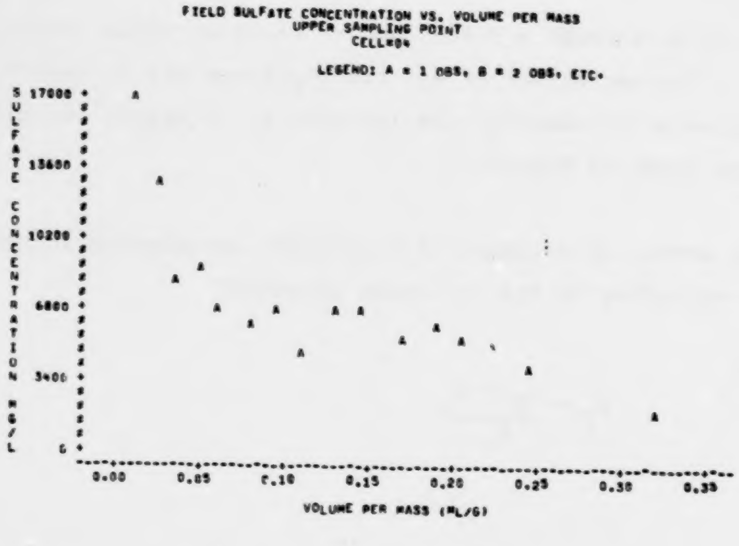


Figure 43f. Field Cell No. 4 (Limestone).

Figure 43. Field Leachate Generation Data for Sulfate (Continued).

The sulfate concentrations in field cell No. 3 (till) leachates are almost twice as high as the concentrations observed for columns No. 1 and No. 2 (Figure 43e). In field cell No. 5 (alluvium), the sulfate concentrations in the leachates are much lower than for the other cells (Figure 43d).

General decreasing sulfate trends are consistent in laboratory and field leachates. Also, the field leachate sulfate concentrations are a factor of four to ten times higher than the laboratory values. A summary of sulfate concentrations and trends for field generated leachates is given in Table 20.

Leachate Attenuation

Five of the six disposal media acquired for this program have been subjected to PFBC leachate in the operating field cells (Table 16). This section discusses the results of leachate and media interaction observed in the field.

Leachate infiltrates through a 3-foot bed of disposal media emplaced below the waste layer. The net effect of all the physico-chemical reactions (attenuation) is evaluated by sampling the leachate as it exists the disposal media (lower sampling array of Figure 7).

For each sample event, an estimate of fractional attenuation in the field cells is made according to the following equation:

$$A_F = \frac{C_U - C_L}{C_U}$$

where

A_F = fractional attenuation (field)

C_U = concentration at upper sampling point (waste leachate)

TABLE 20. FIELD LEACHATE GENERATION COMPARISON FOR SULFATE

Generating Protocol	Concentration Range (mg/ℓ)	Concentration Trend*	Comments
Shale (Field Cell #1)	3,000-27,000	Constant	There is an initial decrease before the concentration levels off; values are much higher than lab values.
Shale (Field Cell #2)	4,000-17,000	Constant	Same trend as above; values are much higher than lab values.
Sandstone (Field Cell #6)	2,500-20,000	Constant	Same trend as above; values are much higher than lab values.
Alluvium (Field Cell #5)	2,000-12,000	Constant	Same trend as above; absolute values are lower.
Glacial Till (Field #3)	4,000-35,000	Constant	Same trend as above; absolute values are higher than for cells #1 and #2.
Limestone (Field Cell #4)	2,500-17,500	Constant	Same trend as above; absolute values are higher than for cells #1 and #2.

*With increasing volume-to-mass ratio.

C_L = concentration at lower sampling point (media leachate)

For example, consider the results for boron from cell No. 1, sample number 6 (12 August 1979). Table 21 presents the observed concentrations and the calculated fractional attenuation.

TABLE 21. EXAMPLE CALCULATION OF FIELD FRACTIONAL ATTENUATION

Concentration at upper sampling point	12.16 mg/ℓ
Concentration at lower sampling point	0.15 mg/ℓ

$$\text{Fractional Attenuation} = \frac{12.16 - 0.15}{12.16} = 0.99$$

If a given constituent is attenuated by the media, then fractional attenuation will be a decimal between 0 and 1. Negative fractional attenuations signify contributions of the constituents to the leachate by the medium.

Two elements of cell operation introduce noise into the pattern of fractional attenuation. The first is the lag between the time a given parcel of water exits the waste mass and the time it exits the underlying medium. This lag is not constant, but varies with the rainfall input. The second element is that the mass flow of contaminants is not congruent with the mass flow of water. Aside from the semi-permanent reactions lumped under the term "attenuation," the incomplete mixing associated with unsaturated media flow provides temporary storage of salts in the interstitial water in the media. The constituents so stored are not attenuated, but are merely delayed.

The following sections present the interaction of PFBC leachate with the five disposal media. For each of the parameters considered under leachate generation (Ca, B, and SO_4) fractional attenuation by each medium is shown.

Calcium--

The attenuation of calcium by the various disposal media is presented in Figures 44a through 44f. The shale (cells 1 and 2) and limestone (cell 4) media contribute calcium to the leachate as does sandstone (cell 6)

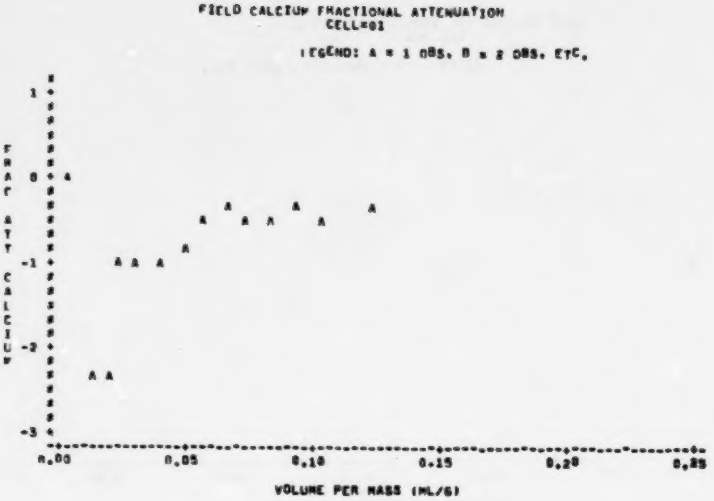


Figure 44a. Field Cell No. 1 (Shale).

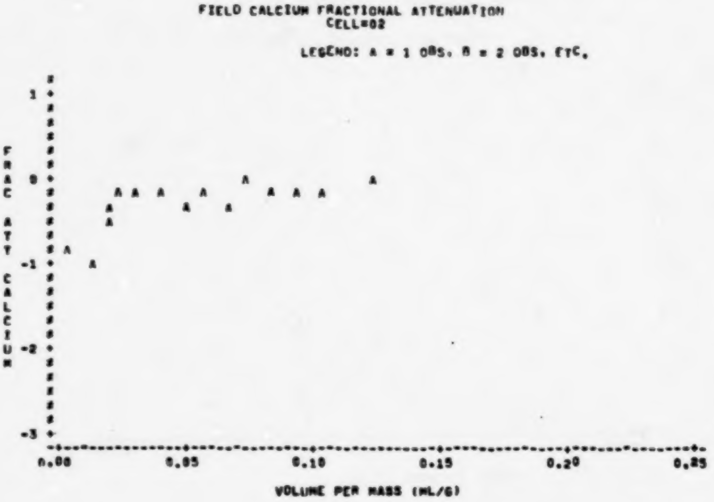


Figure 44b. Field Cell No. 2 (Shale).

Figure 44. Field Fractional Attenuation Data for Calcium.

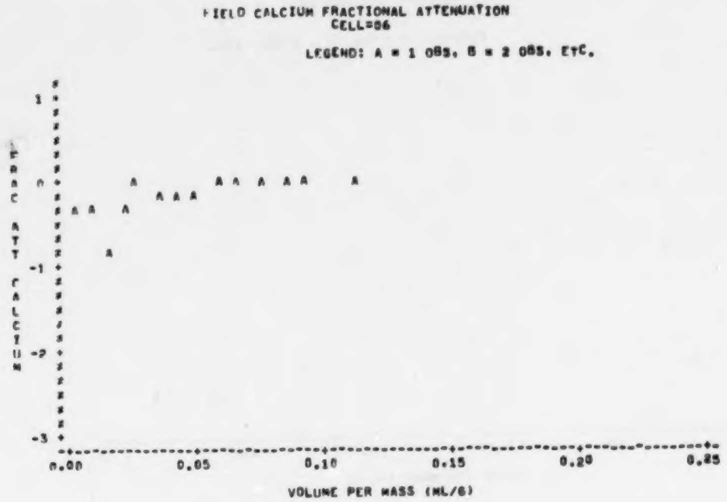


Figure 44c. Field Cell No. 6 (Sandstone).

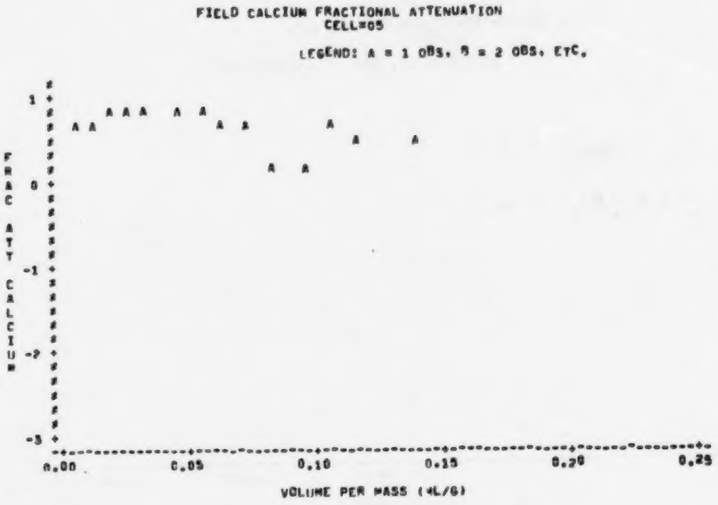


Figure 44d. Field Cell No. 5 (Alluvium).

Figure 44. Field Fractional Attenuation Data for Calcium (Continued).

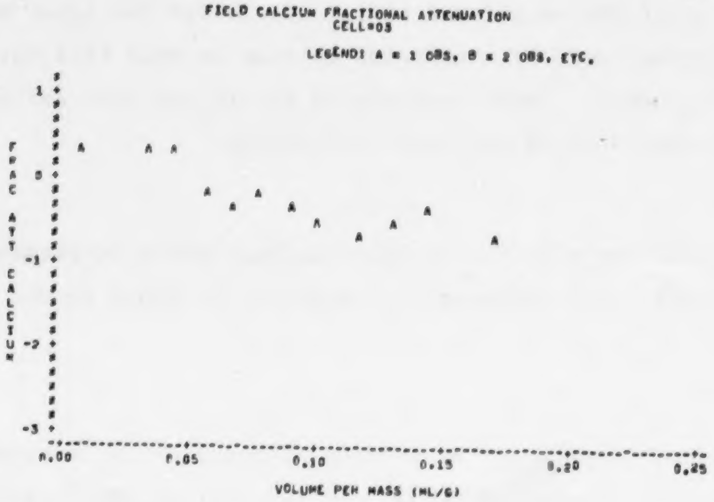


Figure 44e. Field Cell No. 3 (Glacial Till).

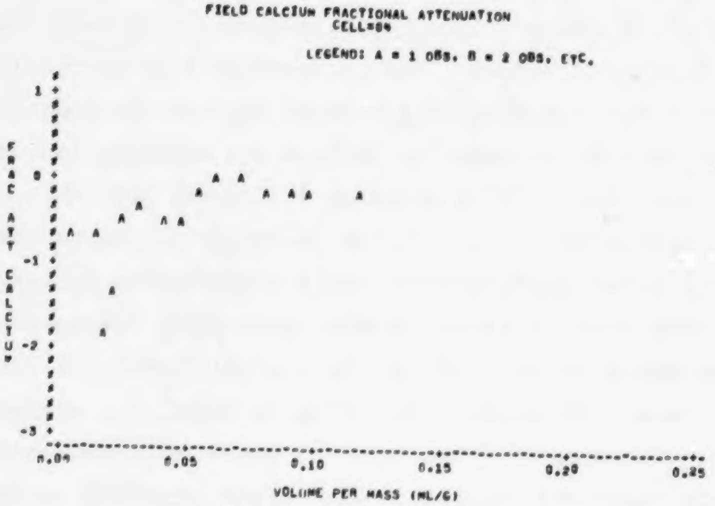


Figure 44f. Field Cell No. 4 (Limestone).

Figure 44. Field Fractional Attenuation Data for Calcium (Continued).

for the early portion of the record and till (cell 3) for the later portion of the record. Alluvium (cell 5) attenuates calcium as does till for the early portion of the record. Later portions of the record show calcium to be unaltered (no attenuation) by the sandstone medium.

Boron--

The attenuation of boron by the various disposal media is presented in Figures 45a through 45f. All media attenuate boron, at least in the early part of the record.

Sulfate--

The attenuation of sulfate by the various disposal media is presented in Figures 46a through 46f. Shale, alluvium, and till all attenuate sulfate, whereas sulfate is unaltered (no attenuation) by both sandstone and limestone.

Observed Field Cell Concentrations

Heretofore, all the data presented have been plotted against a normalized abscissa, i.e., volume of leachate per unit mass of waste or media. It is instructive to consider all observations along a common time axis, represented here by cumulative throughput volume. Thus, concentrations at the upper and lower sample points, as well as available control data may be readily compared. Two examples, one for attenuation and one for mobilization, are discussed here. Field cell No. 1, which contains PFBC waste and shale, provides data indicative of boron attenuation, as seen in Figure 47. Waste leachate from the upper sample point (designated U) has a higher boron content than the leachate contacted with shale collected at the lower point (designated L). Also presented is the concentration of boron in the control field cell (designated C) containing only shale. The control cell clearly identifies minimal boron leaching from shale. Leaching of boron from the waste and attenuation by the shale medium in field tests are consistent with trends observed in the laboratory.

As an alternate sxample, the record for calcium for the same field cell (Figure 48) indicates contamination of the waste leachate by shale. Waste leachate from the upper sample point has a lower calcium concentration than the leachate contacted with shale collected at the lower sample point.

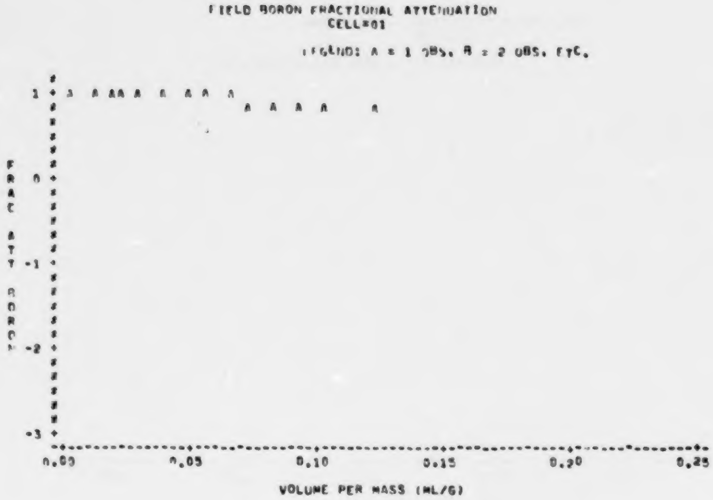


Figure 45a. Field Cell No. 1 (Shale).

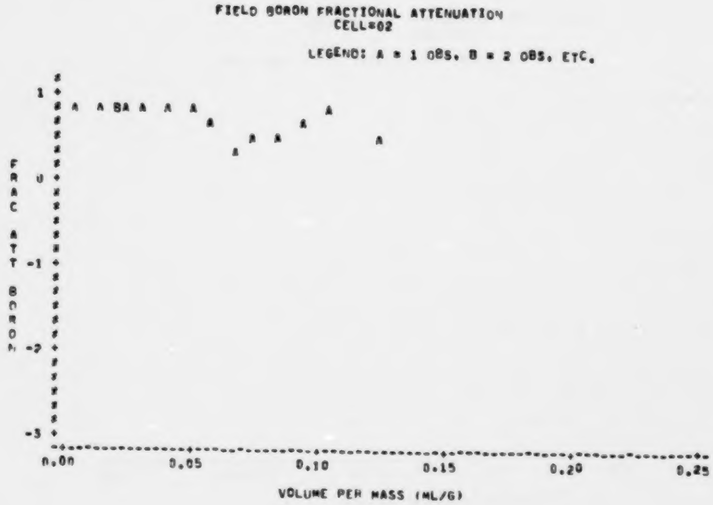


Figure 45b. Field Cell No. 2 (Shale).

Figure 45. Field Fractional Attenuation Data for Boron.

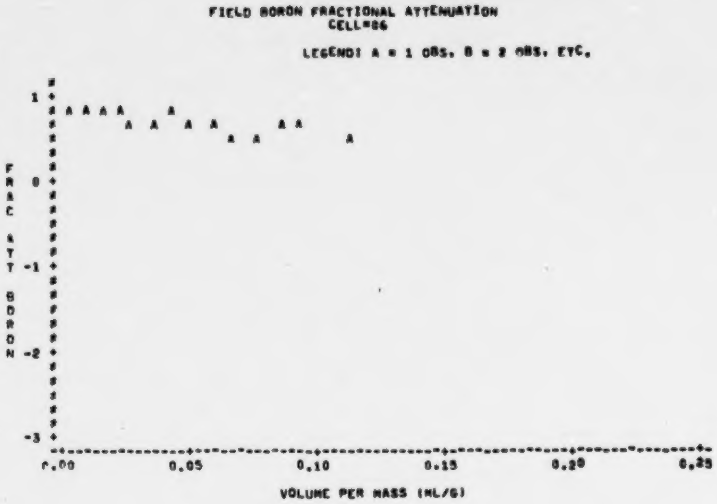


Figure 45c. Field Cell No. 6 (Sandstone).

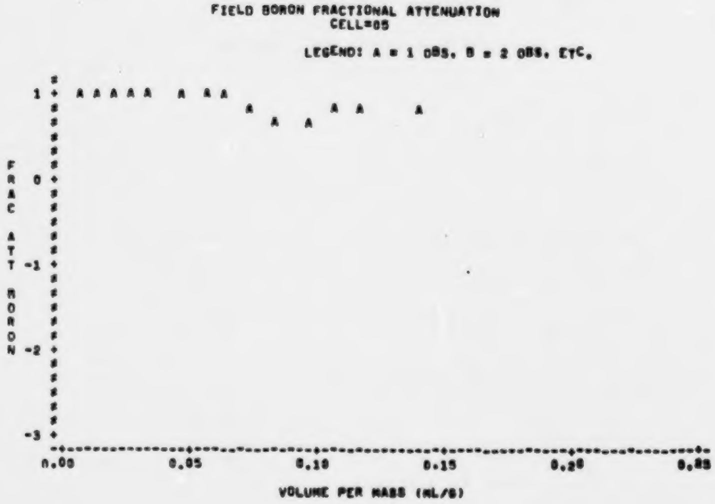


Figure 45d. Field Cell No. 5 (Alluvium).

Figure 45. Field Fractional Attenuation Data for Boron (Continued).

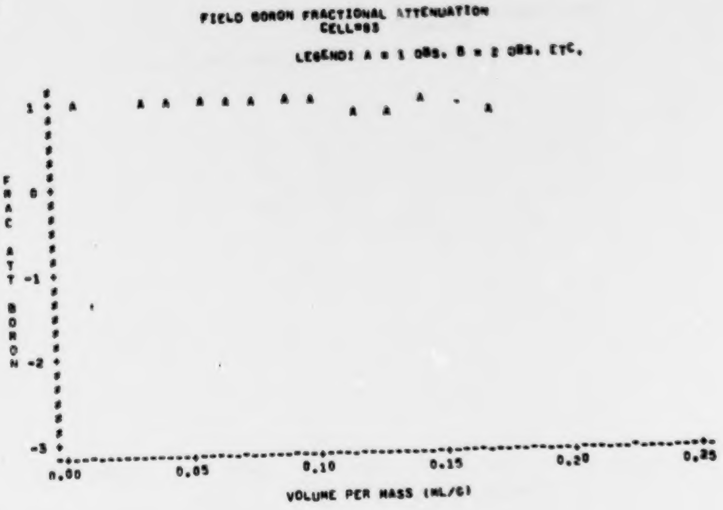


Figure 45e. Field Cell No. 3 (Glacial Till).

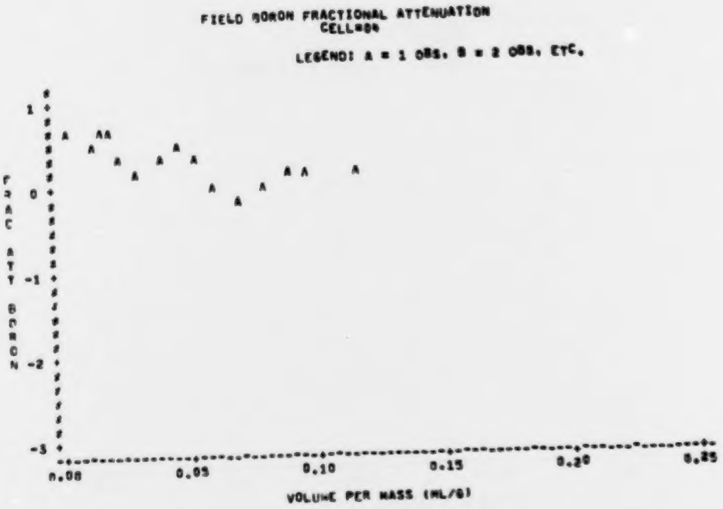


Figure 45f. Field Cell No. 4 (Limestone).

Figure 45. Field Fractional Attenuation Data for Boron (Continued).

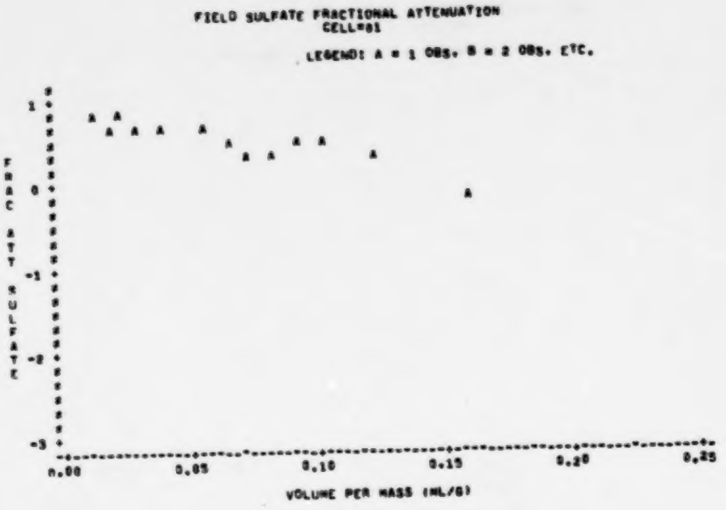


Figure 46a. Field Cell No. 1 (Shale).

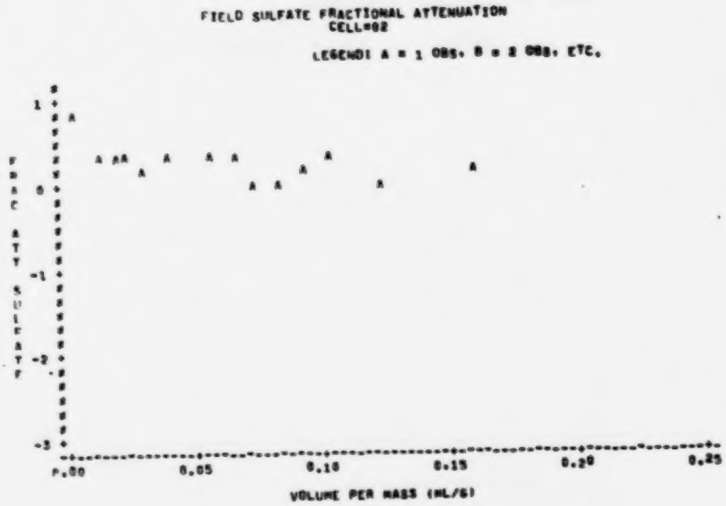


Figure 46b. Field Cell No. 2 (Shale).

Figure 46. Field Fractional Attenuation Data for Sulfate

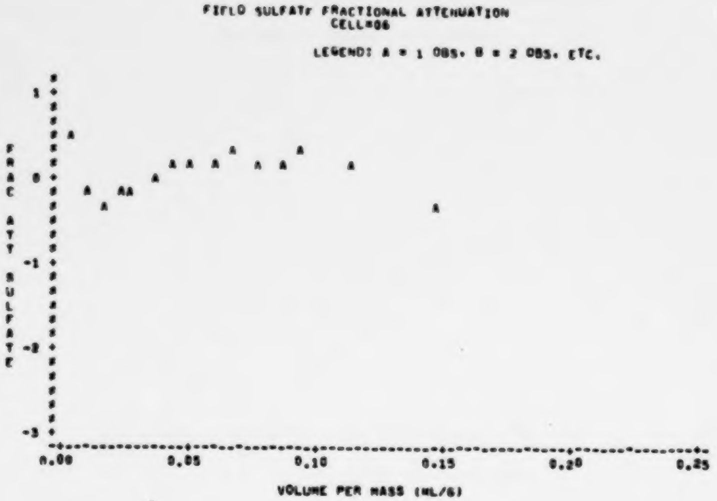


Figure 46c. Field Cell No. 6 (Sandstone).

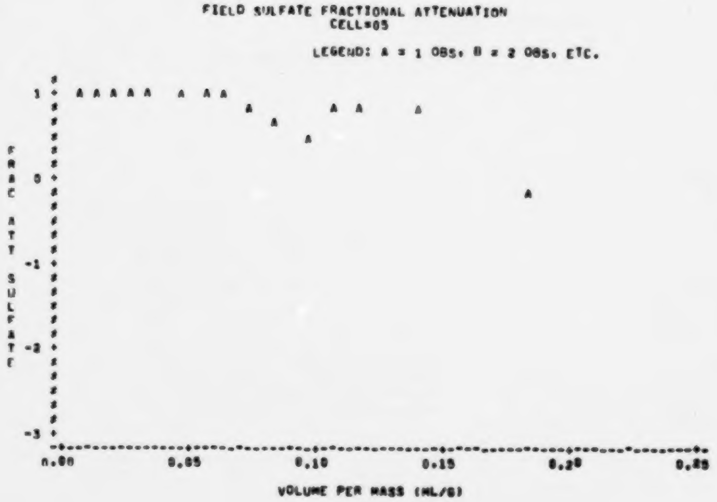


Figure 46d. Field Cell No. 5 (Alluvium).

Figure 46. Field Fractional Attenuation Data for Sulfate (Continued).

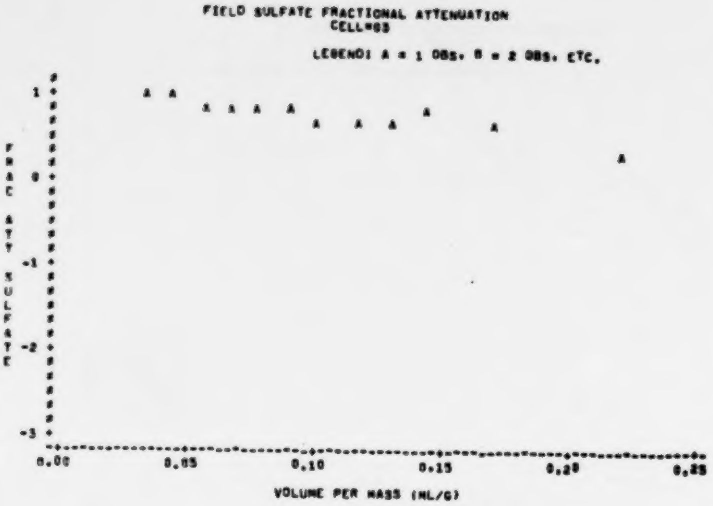


Figure 46e. Field Cell No. 3 (Glacial Till).

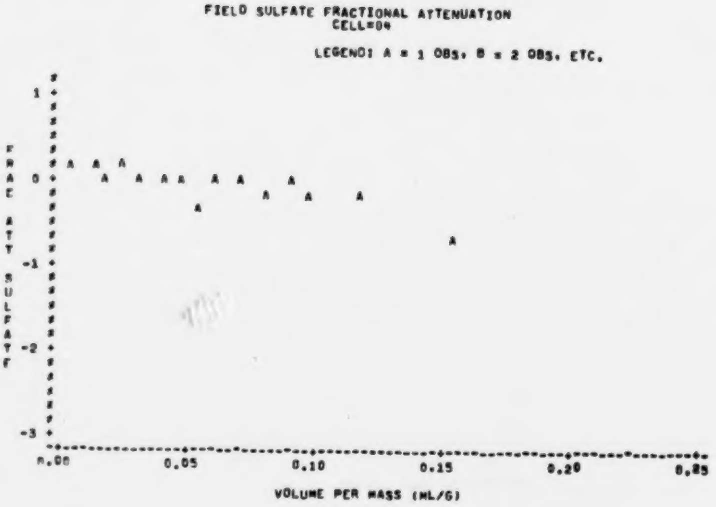


Figure 46f. Field Cell No. 4 (Limestone).

Figure 46. Field Fractional Attenuation Data for Sulfate (Continued).

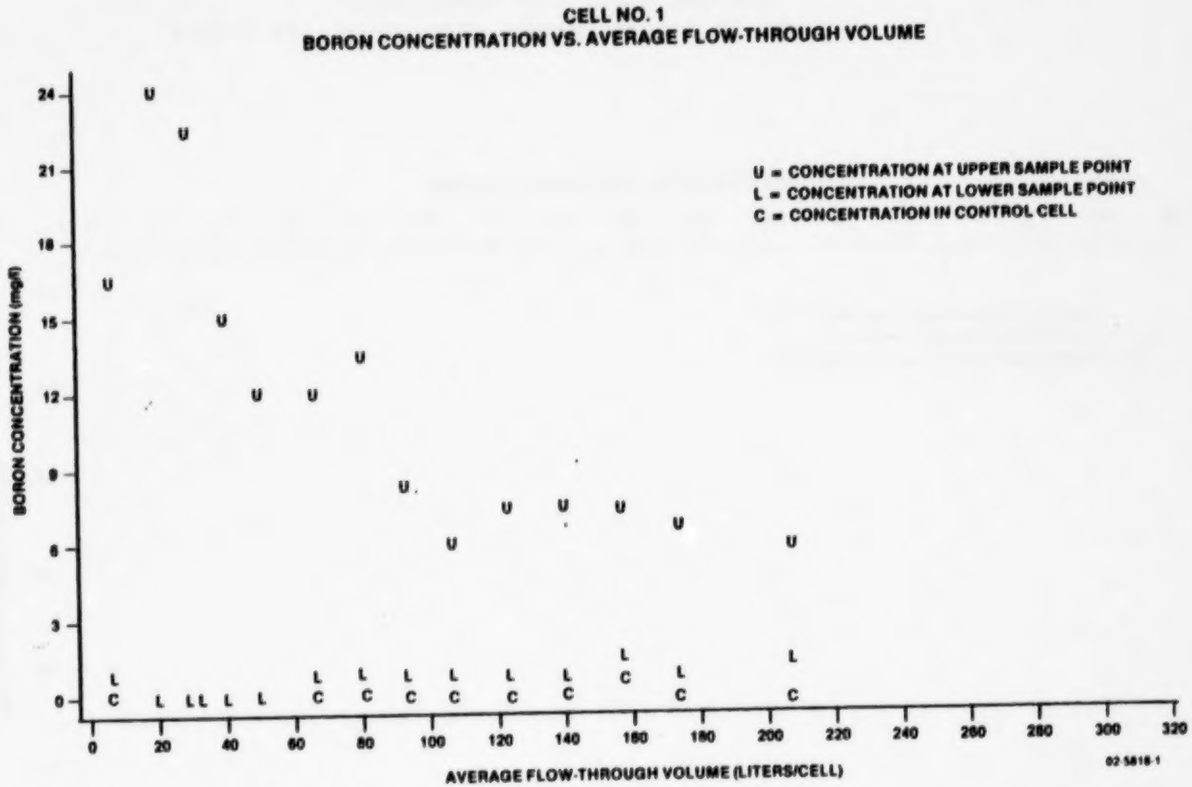


Figure 47. Field Cell Concentrations of Boron (PFBC Waste with Shale Medium).

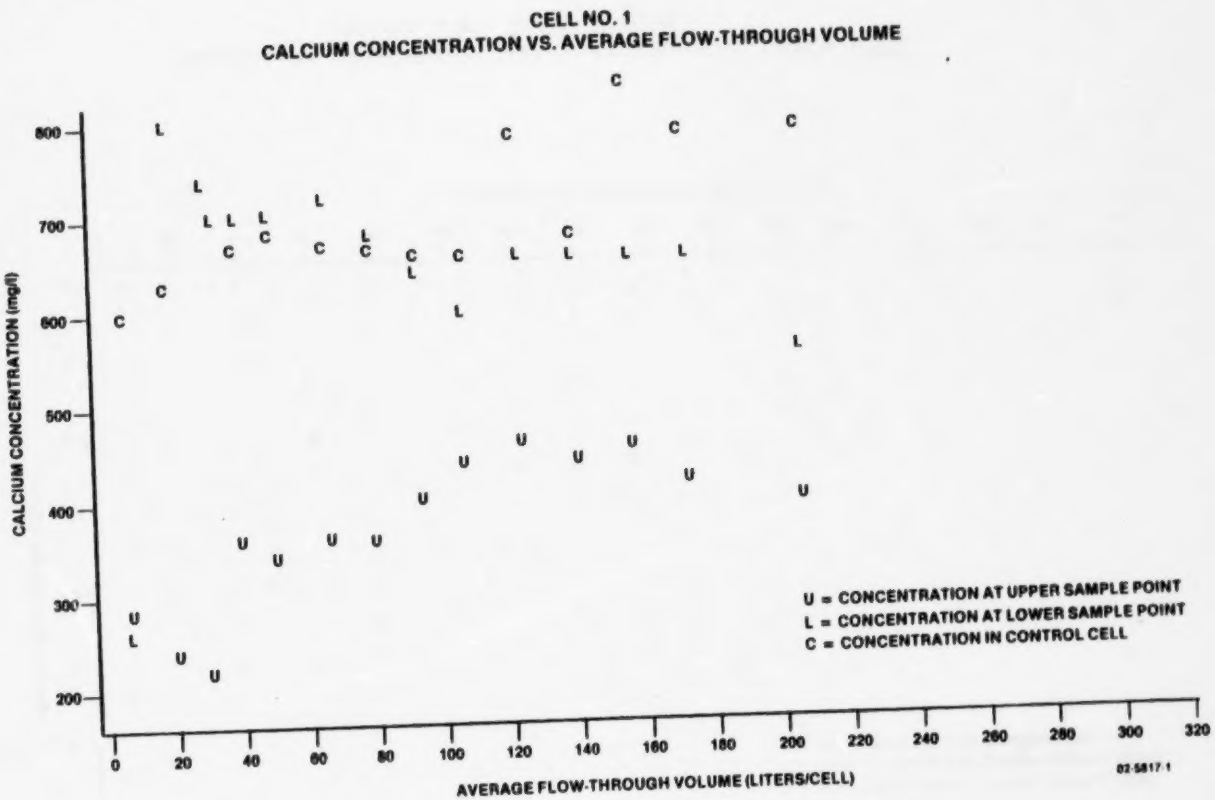


Figure 48. Field Cell Concentrations of Calcium
(PFBC Waste with Shale Medium).

Consideration of Replicate Cells

Field cells No. 1 and 2 both contain shale. These replicate cells were fabricated and filled in the same manner. Their operation will provide a measure of cell-to-cell variation in results. For the data gathered to date, the record of the two cells is similar. Data from cell No. 2 have more scatter than cell No. 1, but the chemical parameters behave similarly. Boron and sulfate are attenuated. Calcium is contributed by the shale.

General Patterns Observed

The three parameters discussed, B, Ca, and SO_4, were selected for illustrative purposes. Calcium and sulfate are major species of FBC wastes; boron demonstrates consistent behavior that provides a clear example of trends discussed. These constituents all behave as do a majority of the 20 parameters measured on field cell leachates. In general, concentrations at the upper sampling point decrease over time. Less commonly, concentrations increase or are roughly constant. At the lower sampling point, trends in concentration are much less consistent. However, the most common occurrences are a relatively constant or gradually increasing concentration over time. The plot of boron concentrations in field cell No. 1 (Figure 47) is a good example of the most common pattern of observations at both the upper and lower sample points.

Another general feature of the analytical record is the tendency for the first one or two samples collected to display concentrations significantly higher (or lower) than succeeding samples. It may well be that these samples were drawn before any equilibrium was established, following the initial irrigation.

ATTENUATING MEDIA COMPARISON

A comparison of attenuation media in laboratory studies can be performed at present, but field comparisons must be approached cautiously due to the short operation period for data reported to date. The available chemical data represent a very limited sample of the field cell operating program. The wastes have been exposured to the equivalent of only one-quarter of the expected annual precipitation input to date.

The relatively dense early sampling schedule is intended to define the expected rapid initial changes in leachate composition. However, early observations are ultimately meaningful only in the light of long-term observations. Patterns of change evident over short time frames may not be reflective of long-term behavior. The full range of possible relationships has simply not been explored at this point in time.

The field and laboratory attenuation data presented in preceding sections may be summarized by grouping similar behavior patterns. Tables 22 and 23 summarize qualitatively the observations to date.

Calcium

Calcium is attenuated by all media in equilibrated lab studies. Field results indicate that all media except alluvium contribute calcium to the leachate. Alluvium attenuation has decreased since testing was begun.

Boron

All media in lab and field studies attenuate boron. In general, field attenuation is not as complete as in the laboratory.

Sulfate

Sulfate is attenuated by all media initially in laboratory studies. However, attenuation decreases with repetitive contact of leachate with the media. Alluvium and limestone contribute sulfate in the later record. No major contribution of sulfate is observed in field studies. Shale, sandstone, alluvium, and till attenuate sulfate, while limestone has no major effect on altering sulfate concentration in the leachate. Limestone in the later record shows minor contribution of sulfate.

TABLE 22. COMPARISON OF MEDIA ATTENUATION BY CONSTITUENT

Constituent	Field Results			Laboratory Results		
	Attenuation	No Effect	Contribution	Attenuation	No Effect	Contribution
Ca	Alluvium Till (early)	Sandstone (late)	Shale Sandstone (early) Till (late) Limestone	Shale Sandstone Alluvium Till Limestone		
B	Shale Sandstone Alluvium Till Limestone			Shale Sandstone Alluvium Till Limestone		
SO_4	Shale	Sandstone Alluvium Till	Sandstone Limestone	Shale Sandstone (early) Alluvium (early Till Limestone (early)	Sandstone (late)	Alluvium (late) Limestone (late)

TABLE 23. COMPARISON OF CONSTITUENTS ATTENUATED OR RELEASED BY MEDIUM

Medium	Field Results			Laboratory Results		
	Attenuated	No Effect	Contribution	Attenuated	No Effect	Contribution
Shale	Ca B SO_4		Ca	Ca B SO_4		
Sandstone	B SO_4	Ca (late	Ca (early)	Ca B SO_4 (early)	SO_4 (late)	
Alluvium	Ca B SO_4			Ca B SO_4 (early)		SO_4 (late)
Glacial Till	Ca (early) B SO_4		Ca (late)	Ca B SO_4		
Limestone	B	SO_4	Ca	Ca B SO_4 (early)		SO_4 (late)

CORRELATION OF LAB AND FIELD RESULTS

The correlation of leaching and attenuation data from laboratory and field studies is an important step in this program. The approach that will be used to relate the outputs of the laboratory and field studies is first described below, and the results of using this approach on data acquired to date as then presented.

Method of Correlation

The expected relationships between shake tests and field cells are shown in Figures 49 to 52. In discussing correlations with the use of these figures, it is assumed that the same waste and disposal medium is being studied in both shake tests and field cells. In addition, a single chemical species "K" is discussed in terms of its behavior in laboratory studies and field studies.

Figure 49 and 50 represent expected concentration behavior in laboratory shake tests. Figure 49 depicts the trend of mass of species "K" leached per gram of waste when it is successively leached. Cumulative mass leached is plotted along the ordinate. Volume along the abscissa is normalized by dividing by the waste mass (mℓ/g).

Figure 50 represents behavior expected for leachate species undergoing attenuation as carried out in laboratory shake tests. The volume axis represents successive contact of leachate with a medium. Volumes are additive as described for exposure of the medium to successive additions of leachate to the waste. The portion of the curve in Figure 50 horizontal to the abscissa represents medium saturation where no further attenuation occurs.

Figure 51 and 52 represent simple projected behavior in field cells. Figure 51 represents the cumulative mass of species "K" at the first sample point where leachate has passed through the waste, prior to entry into the attenuating disposal medium. The abscissa represents the cumulative volume of leachate that has passed through the field cell at the point in time when leachate is collected for analysis.

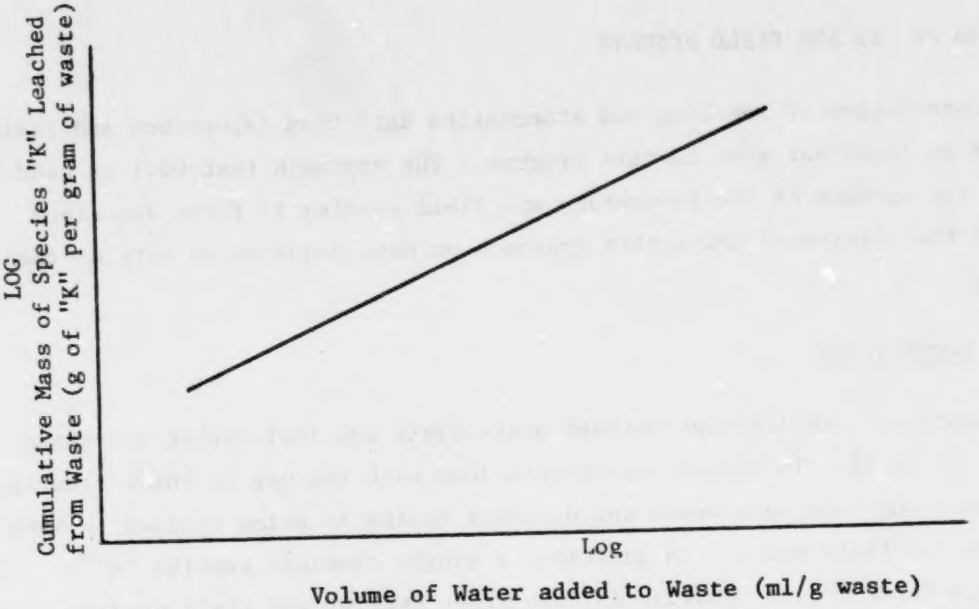
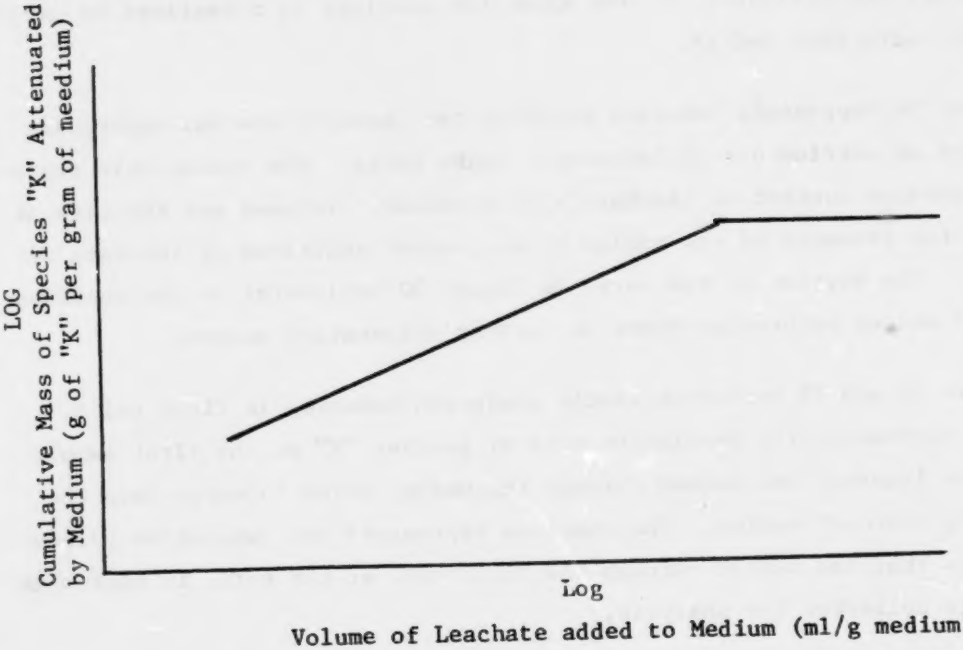


Figure 49. Cumulative Mass of Species "K" Leached in Laboratory Shake Tests as a Function of Volume Added to a Waste



Fiugre 50. Cumulative Mass Differential (Attenuated/Contributed) of a Species "K" in Laboratory Shake Tests as a Function of Volume of Leachate Added to a Disposal Medium

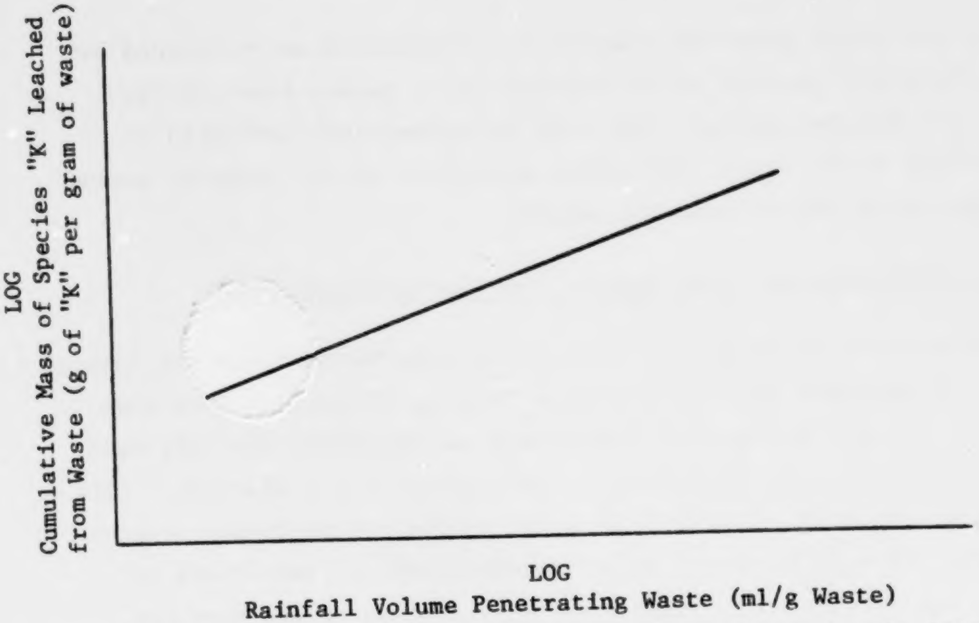


Figure 51. Mass of a Species "K" in Leachate at Upper Sample Point of Field Cell Test as a Function of Rainfall Volume.

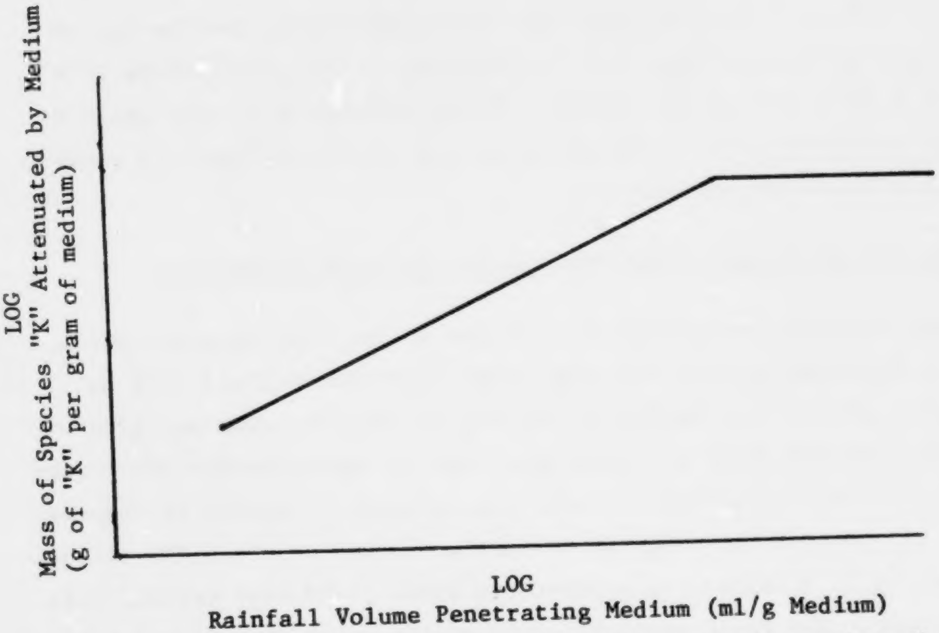


Figure 52. Cumulative Mass Differential (Attenuated/Contributed) of a Species "K" as a Function of Rainfall Volume

Figure 52 represents expected behavior for attenuation as determined by reduction in loading of species in the leachate as it passes from the FBC waste through the disposal medium. The drop in attenuation, indicated by horizontal portion of the curve, represents saturation of the disposal medium from the standpoint of its attenuating ability.

Correlation of Laboratory and Field Results for Leachate Generation

Figure 53 presents leaching results observed thus far in field and laboratory studies. It presents data equivalent to Figures 49 and 51. Data from field cell No. 1 (shale) are presented for seven parameters on the left hand portion of the figure in the low volume-to-mass region of the abscissa. Data for the laboratory studies are presented in the higher volume-to-mass region. The lab results, although displaced in volume approximately two orders of magnitude from the field results, appear to be in good agreement thus far with field results of cumulative mass leached for six of the seven species. However, the results for magnesium do not appear to follow this trend. Continued monitoring of the field cell waste leachate will validate this correlation by extending this region of field results nearer the lab data. It appears at this time that correlation of laboratory with field results may be possible. Future program efforts will be directed toward establishing this correlation on a sound statistical basis. Future efforts will also include other disposal media and other chemical parameters in the attempts to establish a statistically sound correlation.

Correlation of Laboratory and Field Results for Leachate Attenuation

Attenuation results are presented in Figure 54 for four species (boron, sulfate, total dissolved solids, and magnesium) observed in field cell No. 1 containing shale medium. The cumulative attenuated mass in grams per gram of medium for field and lab data are again separated by approximately two orders of magnitude. A good correlation of field and laboratory results is observed for sulfate. Lab results may slightly overestimate the boron and TDS attenuation. However, it is premature to predict the final field cell results this early in the study. The field results for magnesium are without trend and are slightly higher than anticipated from extrapolation of lab results. Future

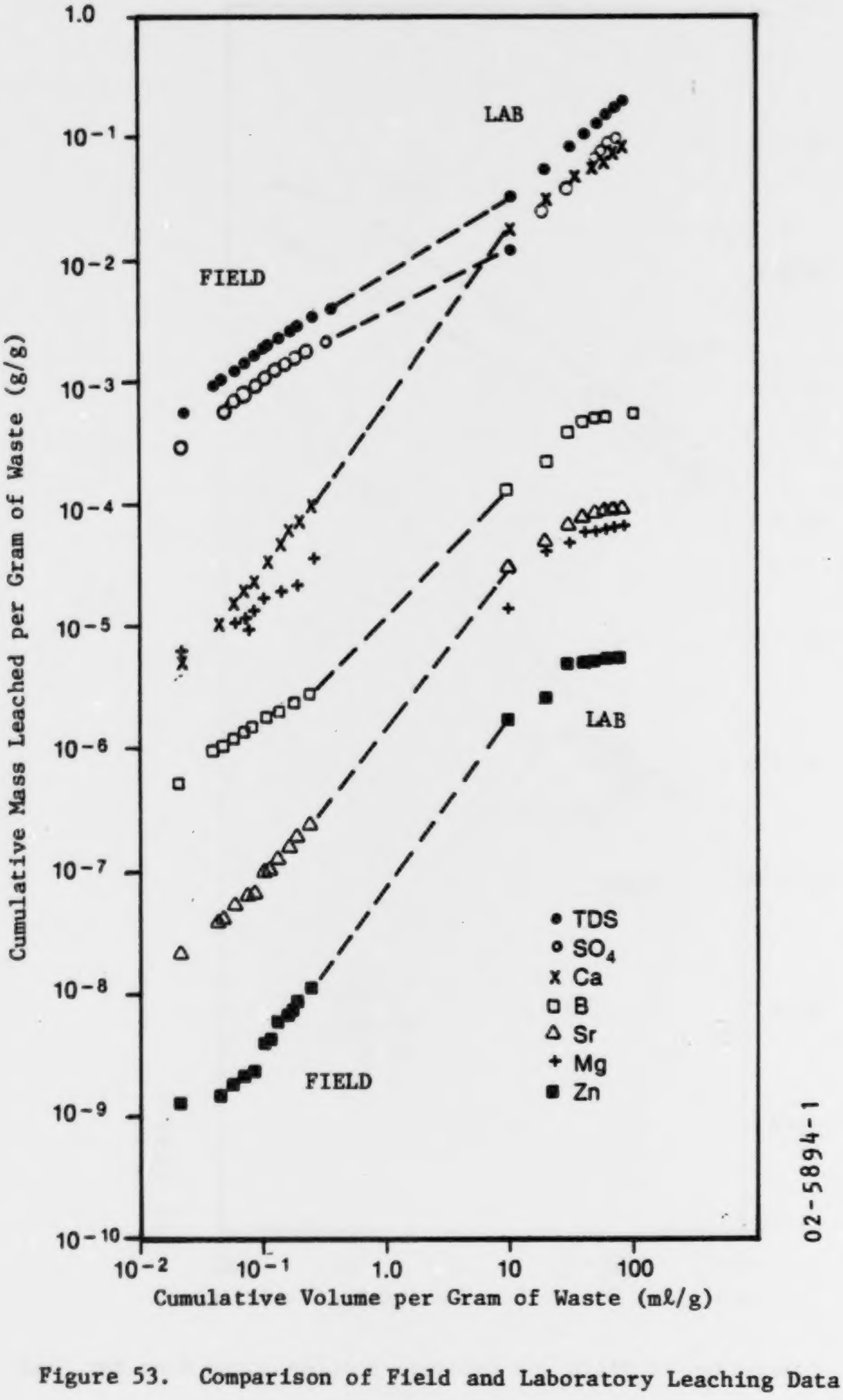


Figure 53. Comparison of Field and Laboratory Leaching Data

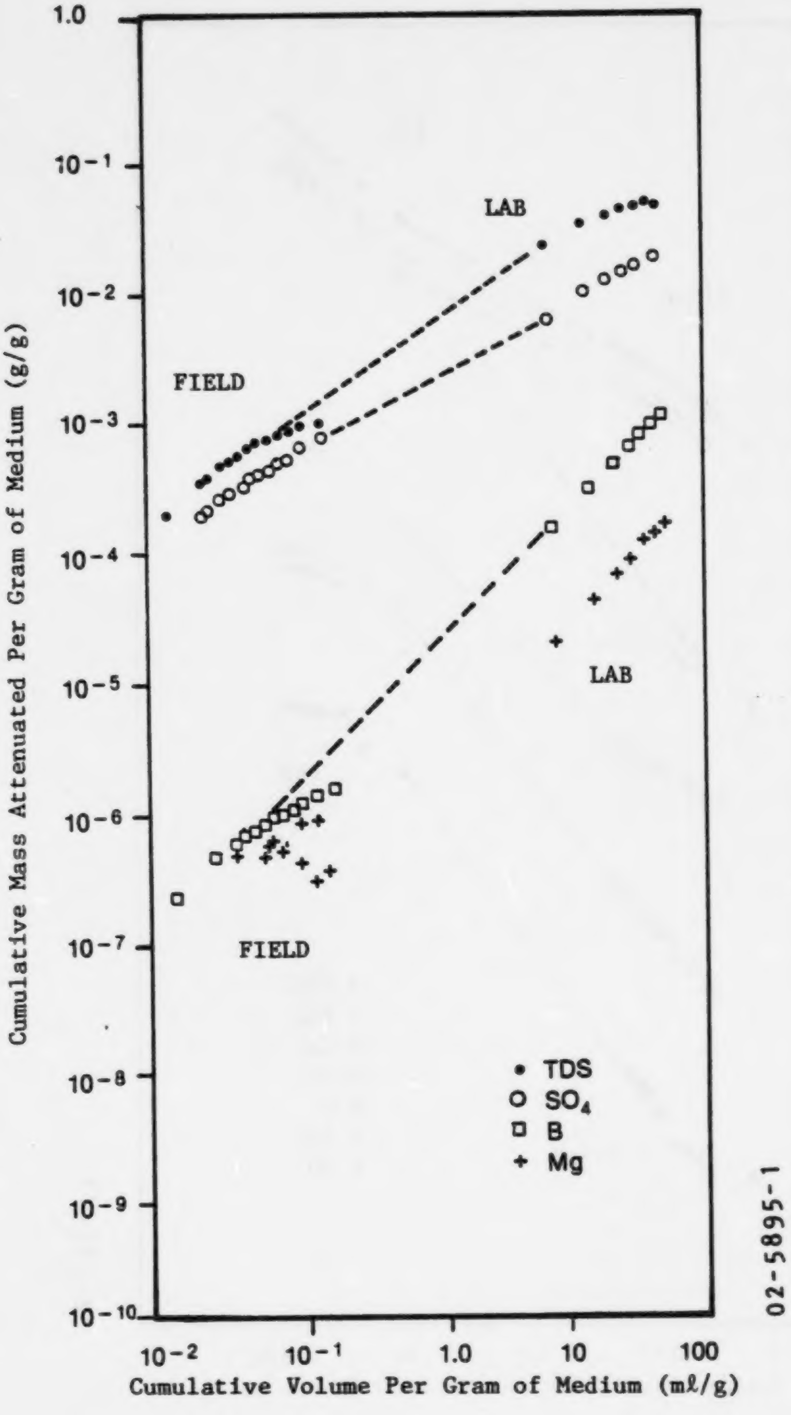


Figure 54. Comparison of Field and Laboratory Attenuating Data for Shale

program efforts will establish which parameters can be reliably correlated and will also include other disposal media in the correlation studies.

Field Results Indicating Contaminant Mobilization in the Disposal Media

For three species (calcium, strontium, and zinc), the concentration level after interaction with the shale medium in the field is higher than before interaction. This indicates leaching of these species from the shale itself. The degree of leaching (contamination) from the shale medium is presented in Figure 55. While cumulative mass of calcium and strontium contributed by the shale medium appear to be volume dependent, results for zinc are not as consistent and may be indicative of either analysis problems near the detection limit or unknown release mechanisms due to the chemistry of the cell conditions.

Calcium, strontium, and zinc are attenuated in the lab studies. Field studies to date are in disagreement with this observation. Future monitoring of the field cells may indicate either an initial conditioning of the medium prior to attenuation of these species or that lab studies cannot be correlated for these parameters. In either case, the use of the attenuation plot for field results (Figure 54) will be of importance in comparing species attenuation by the six media.

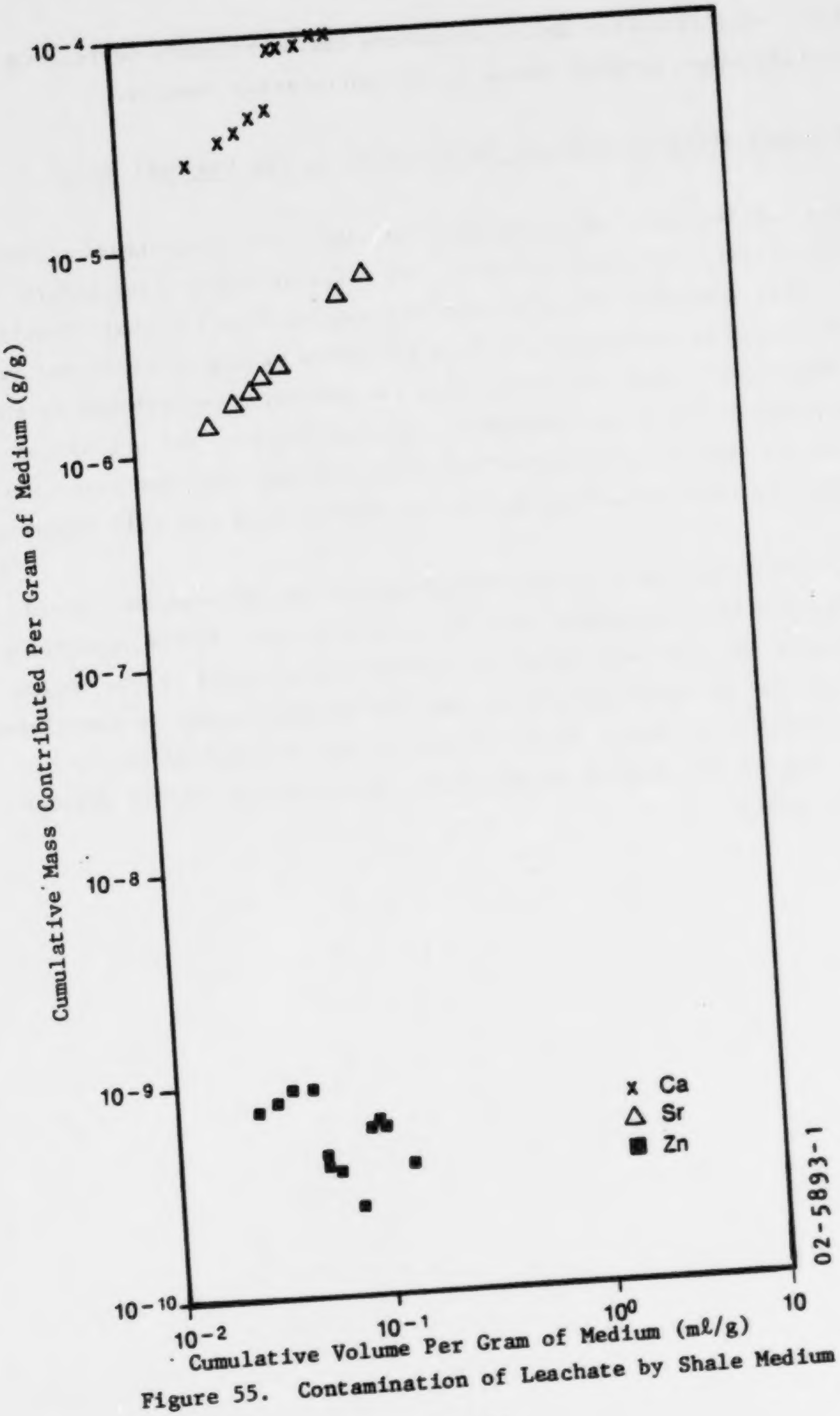


Figure 55. Contamination of Leachate by Shale Medium

SECTION 5

COMPARISON OF CHEMICAL ANALYTICAL RESULTS WITH WATER QUALITY CRITERIA AND STANDARDS

The purpose of this section is to evaluate the characteristics of FBC residues and their interaction with natural disposal media by providing a context for the quality of the residue leachate. This context is provided by comparing the leachate quality with water quality criteria, regulations, and standards for several inorganic chemical parameters. As noted in Section 1, the determination of FBC residue and leachate characteristics before and after the interaction of the leachate with natural disposal media is one of the two major objectives of this investigation.

The chemical analytical data resulting from the laboratory and field studies of this program are presented in Appendix I. These data include analyses of samples of leachate generated from PFBC wastes and analyses of PFBC leachate that have been exposed to the six disposal media. The data reported in the Appendix are preliminary and have not yet been fully edited for erroneous entries or data excursions.

The first step in drawing a comparison between the quality of leachate and the appropriate water quality standards and criteria is to tabulate the summary chemical data from laboratory and field studies with the corresponding values set forth in the standards and criteria. Table 24 presents a summary of the analytical data from the laboratory studies along with four sets of water quality criteria.[8,9,10,13] Data are presented in this table for Protocol Steps 1 and 4 in order to allow the comparison to be drawn for leachate generated by contact of fresh water with PFBC waste and for leachate that has been exposed to fresh disposal media. Future reports will present similar findings for all protocol steps. Columns 2 through 4 of the table

TABLE 24. COMPARISON OF PRELIMINARY LABORATORY CHEMICAL ANALYTICAL RESULTS WITH WATER QUALITY CRITERIA AND REGULATIONS

Parameter	Primary or Secondary Drinking Water Regulations	DMEG Values (Health/ Ecology)	Quality Criteria for Water	Leachate Generation (Protocol Step No. 1)	Leachate Attenuation (Protocol Step No. 4)					
					Shale	Sandstone	Alluvium	Glacial Till	Limestone	Interburden
Aluminum	N[a]	80/1.0	N	0.614	0.152	0.469	1.021	0.857	1.727	0.299
Arsenic	0.05 (P)	0.25/0.05	0.05[b]	<0.08	<0.08	<0.08	N.D.	N.D.	N.D.	<0.08
Barium	1.0 (P)	5.0/2.5	1.0[b]	0.171	0.221	0.095	0.233	0.157	0.190	0.116
Boron	N	47/25	0.75[c]	13.3	0.396	0.136	0.431	0.768	0.639	0.460
Cadmium	0.01 (P)	0.05/0.001	0.01[b]	<0.005	0.189	<0.005	<0.005	<0.005	0.024	<0.005
Calcium	N	240/16	N	1700	505	996	545	560	549	1000
Chloride	250 (S)	N	250[d]	4.46	10.0	9.45	N.D.	N.D.	N.D.	9.6
Chromium	0.05 (P)	0.25/0.25	0.05[b] 0.10[e]	0.0597	0.0337	0.054	0.102	0.084	0.124	0.049
Cobalt	N	0.75/0.25	N	<0.15	<0.15	0.434	1.53	1.27	2.84	0.124
Copper	1 (S)	5.0/0.05	1.0[b]	<0.005	0.168	0.0278	0.103	0.107	0.165	0.010
Fluoride	2.0 @ 60°F (P)	N	N	0.785	0.415	0.403	0.265	0.625	0.635	0.708
Iron	0.3 (S)	N	0.3[b] 1.0[e]	0.224	0.418	0.239	0.177	0.059	0.099	0.055
Lead	0.05 (P)	0.25/0.05	0.05[b]	<0.07	<0.07	<0.07	N.D.	N.D.	N.D.	<0.07
Lithium	N	0.375/N	N	N.D.[g]	<0.01	<0.01	0.01	<0.01	0.02	<0.01
Magnesium	N	90/87	N	1.91	0.080	0.060	0.0025	0.0035	0.0086	0.027
Manganese	0.05 (S)	0.25/0.10	0.05[b]	0.003	0.193	0.0053	0.182	0.011	0.022	0.0016
Mercury	0.002 (P)	0.01/0.25	0.002[b] 0.00005[e] 0.0001[f]	N.D.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	N	75/7		N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Nickel	N	0.225/0.010	N	<0.0124	0.171	0.103	0.186	0.186	0.275	0.055
Potassium	N	30/23	N	<40	3.5	187	494	429	848	107
Selenium	0.01 (P)	0.05/0.025	0.01[b]	<0.12	<0.0625	<0.0625	<0.005	<0.005	<0.005	<0.0625
Silicon	N	N	N	0.669	1.080	0.816	1.18	2.50	1.13	1.09
Silver	0.05 (P)	0.25/0.005	0.05[b]	<0.005	<0.005	0.029	0.0914	0.078	0.175	0.0093
Sodium	N	N	N	15.0	13.5	11.9	<5	<5	6.62	9.45
Strontium	N	46/N	N	2.93	2.03	2.79	1.58	1.09	2.83	2.85
Sulfate	250 (S)	N	250[b,d]	1225	723	938	740	940	720	1175
Titanium	N	90/0.82	N	<0.002	0.167	0.018	0.046	0.040	0.072	0.012
Uranium	N	60/0.500	N	N.D.	<0.3	<0.3	N.D.	N.D.	N.D.	<0.03
Vanadium	N	2.5/0.15	N	<0.01	0.153	0.037	0.114	0.102	0.216	0.017
Zinc	5 (S)	25/0.100	5.0[b]	0.171	0.221	0.077	0.015	0.014	0.035	0.094
pH (pH units)	6.5-8.5 (S)	N	5-9[b] 6.5-9[e] 6.5-8.5[f]	11.8	10.9	12.0	11.1	9.32	11.9	11.6
TOC	N	N	N	1.1	3.3	2.55	3.8	N.D.	2.65	4.45
TDS	500 (S)	N	250[d]	3210	1295	1888	1055	1660	1673	2038
Conductivity (umhos)	N	N	N	9530	2410	3590	1530	1580	2630	3470

[a] N - No values given.

[b] Criterion for domestic water supplies (health).

[c] Criterion for long-term irrigation on sensitive crops.

Values in body of table are in mg/l, except as noted.

[d] 250 mg/l is the criterion for chlorides and sulfates (total) in domestic water supplies (welfare).

[e] Criterion for freshwater aquatic life.

[f] Criterion for marine aquatic life.

[g] N.D. - Not Determined.

present water quality criteria and standards from four sources. Column 5 presents the results from Protocol Step 1 (the initial leachate generation step). These values are derived by averaging the results of eight separate analyses. Only the seven-day (not the one-day and two-day) leachate results are given. Columns 6 through 11 present the results from Protocol Step 4 (the initial attenuation step) for each of the six disposal media. For purposes of the comparisons discussed in this section, the ICPES data in Column 5 (leachate generation) for arsenic, lead, mercury and selenium were replaced by the corresponding values from Table 11, which were determined by more sensitive atomic absorption techniques.

Tables 25 and 26 contain the necessary data for comparison of the results of field studies with the water quality criteria and standards. Columns 2 through 4 of both tables contain the same water quality criteria and standards as those in Table 24. Columns 5 through 10 of Table 25 present the leachate generation data for each of the field cells containing PFBC waste. These data are for leachates collected at the upper sampling point just below the lift of waste. The concentration shown is the volume-weighted average of the leachate samples collected. Columns 5 through 10 of Table 26 contain leachate attenuation data for each field cell. These data are for leachate collected from the lower sampling point below the lift of disposal media. As in the data for the upper sampling point, the value shown is the volume-weighted average concentration. Columns 11 and 12 of Table 26 contain the data for the two field control cells, which contain shale and alluvium but no PFBC waste. The pH and electrical conductivity values in both Table 25 and Table 26 are presented as a range of values observed.

The data presented in Tables 24, 25, and 26 have been examined, and conclusions have been drawn concerning the concentrations of various leachate parameters in comparison to the corresponding water quality criteria and standards. For each criterion or standard, a discharge severity (DS) has been calculated. The DS is the ratio of the observed concentration to the reference (criterion, standard) concentration. Each parameter is assigned to a category of significance, based on DS. These categories are:

TABLE 25. COMPARISON OF PRELIMINARY FIELD CELL CHEMICAL ANALYTICAL RESULTS WITH WATER QUALITY CRITERIA AND STANDARDS: UPPER SAMPLE POINT (LEACHATE GENERATION)

Parameter	Primary or Secondary Drinking Water Regulations	DMEG Values (Health/ Ecology)	Quality Criteria for Water	Leachate Generation (Upper Sample Point)					
				Shale Field Cell #1	Shale Field Cell #2	Sandstone Field Cell #6	Alluvium Field Cell #5	Glacial Till Field Cell #3	Limestone Field Cell #4
Aluminum	N[a]	80/1.0	N	0.0168	0.151	0.219	0.142	0.0179	0.154
Arsenic	0.05 (P)	0.25/0.05	0.05[b]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Barium	1.0 (P)	5.0/2.5	1.0[b]	0.107	0.0978	0.0966	0.096	0.096	0.116
Boron	N	47/25	0.75[c]	11.1	7.86	7.32	4.9	11.4	11.6
Cadmium	0.01 (P)	0.05/0.001	0.01[b]	0.00528	<0.005	0.00503	0.00502	0.00564	0.00512
Calcium	N	240/16	N	377	434	435	323	355	353
Chloride	250 (S)	N	250[d]	181	107	N.D.	N.D.	176	157
Chromium	0.05 (P)	0.25/0.25	0.05[b] 0.10[e]	0.0939	0.0749	0.102	0.043	0.0964	0.115
Cobalt	N	0.75/0.25	N	0.175	0.218	0.176	0.183	0.185	0.168
Copper	1 (S)	5.0/0.05	1.0[b]	0.00538	0.00621	0.00546	0.00574	0.00543	0.00626
Fluoride	2.0 @ 60°F (P)	N	N	0.27	0.283	0.299	0.256	0.245	0.303
Iron	0.3 (S)	N	0.3[b] 1.0[e]	0.0296	0.0258	0.132	0.0144	0.00334	0.272
Lead	0.05 (P)	0.25/0.05	0.05[b]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Lithium	N	0.375/N	N	3.91	2.61	3.22	3.7	3.92	3.7
Magnesium	N	90/87	N	149	132	200	17.1	229	175
Manganese	0.05 (S)	0.25/0.10	0.05[b]	2.14	3.1	0.71	0.92	2.43	0.59
Mercury	0.002 (P)	0.01/0.25	0.002[b] 0.00005[e] 0.0001[f]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Molybdenum	N	75/7	N	0.509	0.339	0.406	0.348	0.551	0.642
Nickel	N	0.225/0.010	N	0.104	0.123	0.12	0.0731	0.112	0.101
Potassium	N	30/23	N	826	491	489	660	928	622
Selenium	0.01 (P)	0.05/0.025	0.01[b]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Silicon	N	N	N	39.1	37.8	45	79	27.9	43.6
Silver	0.05 (P)	0.25/0.005	0.05[b]	0.0153	0.0199	0.016	0.0161	0.0185	0.0137
Sodium	N	N	N	400	163	237	161	261	568
Strontium	N	46/N	N	0.956	1.38	1.05	1.34	0.539	0.971
Sulfate	250 (S)	N	250[b,d]	7490	5460	6560	5460	8690	7980
Titanium	N	90/0.82	N	0.0166	0.0171	0.0178	0.00706	0.0156	0.0138
Uranium	N	60/0.500	N	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Vanadium	N	2.5/0.15	N	0.47	0.419	0.564	0.109	0.66	0.496
Zinc	5 (S)	25/0.100	5.0[b]	0.044	0.101	0.0406	0.00787	0.083	0.0477
pH (pH units)	6.5-8.5 (S)	N	5-9[b] 6.5-9[e] 6.5-8.5[f]	7.47-8.28	7.40-8.13	7.32-9.64	7.40-12.1	7.36-8.52	7.30-8.19
TOC	N	N	N	15.1	11.6	14.9	13.3	13.2	22.3
TDS	500 (S)	N	250[d]	13,400	9820	10,800	10,200	15,300	14,400
Conductivity (µmhos)	N	N	N	9500-38,000	7300-22,000	5400-40,000	5500-30,000	7100-47,000	4700-28,400

[a] N - No values given.

[b] Criterion for domestic water supplies (health).

[c] Criterion for long-term irrigation on sensitive crops.

Values in body of table are in mg/1, except as noted.

[d] 250 mg/1 is the criterion for chlorides and sulfates (total) in domestic water supplies (welfare).

[e] Criterion for freshwater aquatic life.

[f] Criterion for marine aquatic life.

[g] N.D. - Not Determined.

TABLE 26. COMPARISON OF PRELIMINARY FIELD CELL CHEMICAL ANALYTICAL RESULTS WITH WATER QUALITY CRITERIA AND STANDARDS: LOWER SAMPLE POINT (LEACHATE ATTENUATION) AND CONTROL CELLS

				Leachate Attenuation (Lower Sample Point)						Control Field Cells	
Parameter	Primary or Secondary Drinking Water Regulations	DMEG Values (Health/ Ecology)	Quality Criteria for Water	Shale Field Cell #1	Shale Field Cell #2	Sandstone Field Cell #6	Alluvium Field Cell #5	Glacial Till Field Cell #3	Limestone Field Cell #4	Shale Field Cell #7	Alluvium Field Cell #12
Aluminum	N[a]	80/1.0	N	0.166	0.160	0.231	0.113	0.142	0.163	0.185	0.0862
Arsenic	0.05 (P)	0.25/0.05	0.05[b]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Barium	1.0 (P)	5.0/2.5	1.0[b]	0.0818	0.0728	0.0531	0.13	0.178	0.0731	0.074	0.138
Boron	N	47/25	0.75[c]	0.684	2.03	1.88	0.615	0.554	6.84	0.128	0.0723
Cadmium	0.01 (P)	0.05/0.001	0.01[b]	<.005	<.005	<.005	<.005	<.005	<.005	<.005	0.00511
Calcium	N	240/16	N	659	508	474	134	474	452	721	49.1
Chloride	250 (S)	N	250[d]	123	136	N.D.	39.6	137	326	N.D.	N.D.
Chromium	0.05 (P)	0.25/0.25	0.05[b] 0.10	0.0735	0.0701	0.124	0.0214	0.0623	0.0797	0.0629	0.00631
Cobalt	N	0.75/0.25	N	0.267	0.232	0.44	0.153	0.161	0.2	0.256	<0.15
Copper	1 (S)	5.0/0.05	1.0[b]	0.00896	0.0104	0.00703	0.00586	0.00506	0.00679	0.00646	0.00502
Fluoride	2.0 @ 60°F (P)	N	N	0.179	0.201	0.387	0.233	0.349	1.83	0.143	0.122
Iron	0.3 (S)	N	0.3[b] 1.0[e]	0.0307	0.0274	0.0668	0.0729	0.0254	0.0318	0.0308	0.0501
Lead	0.05 (P)	0.25/0.05	0.05[b]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Lithium	N	0.375/N	N	0.0932	0.431	1.24	0.0801	0.103	2.99	0.0391	0.0448
Magnesium	N	90/87	N	141	147	275	21.9	121	182	115	6.36
Manganese	0.05 (S)	0.25/0.10	0.05[b]	1.14	1.02	22.1	2.72	0.94	0.752	0.426	0.9
Mercury	0.002 (P)	0.01/0.25	0.002[b] 0.00005[e] 0.0001[f]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Molybdenum	N	75/7	N	0.157	0.129	0.159	0.0522	0.0786	0.93	0.165	<0.04
Nickel	N	0.225/0.010	N	0.138	0.128	0.453	0.0777	0.103	0.263	0.134	0.035
Potassium	N	30/23	N	279	331	251	104	171	410	215	47.1
Selenium	0.01 (P)	0.05/0.025	0.01[b]	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Silicon	N	N	N	28.9	25.4	23.9	24.2	52.8	36.7	21.2	20.3
Silver	0.05 (P)	0.25/0.005	0.05[b]	0.0225	0.0157	0.0313	0.00841	0.0127	0.0161	0.0252	0.00505
Sodium	N	N	N	105	151	152	20.3	25.2	798	<5	<5
Strontium	N	46/N	N	1.84	1.75	2.11	0.589	0.769	9.38	1.8	0.23
Sulfate	250 (S)	N	250[b,d]	3300	4040	5050	705	1660	7600	1870	95.1
Titanium	N	90/0.82	N	0.0236	0.018	0.0236	0.00342	0.0142	0.0169	0.0247	0.00248
Uranium	N	60/0.500	N	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Vanadium	N	2.5/0.15	N	0.475	0.449	0.691	0.123	0.45	0.48	0.397	0.034
Zinc	5 (S)	25/0.100	5.0[b]	0.0482	0.046	0.259	0.0569	0.0495	0.0785	0.0706	0.0596
pH (pH units)	6.5-8.5 (S)	N	5-9[b] 6.5-9[e] 6.5-8.5[f]	7.10-7.56	7.14-7.80	6.98-7.78	5.52-7.90	7.21-7.67	7.43-7.96	6.94-7.58	6.39-7.84
TOC	N	N	N	12.6	8.02	5.66	7.45	17	17.5	9.73	8.47
TDS	500 (S)	N	250[d]	6080	7290	8410	1340	3300	14,100	3780	256
Conductivity (μmhos)	N	N	N	4850-6750	6000-8400	6500-11,500	246-5250	1520-4500	6800-22,300	2790-3800	195-934

[a] N - No values given.

[b] Criterion for domestic water supplies (health).

[c] Criterion for long-term irrigation on sensitive crops.

Values in body of table are in mg/l, except as noted.

[d] 250 mg/l is the criterion for chlorides and sulfate (total) in domestic water supplies (welfare).

[e] Criterion for freshwater aquatic life.

[f] Criterion for marine aquatic life.

[f] N.D. - Not Determined.

- Category 1: DS <1. The analytical results are less than the criterion. The leachate poses no health or environmental threat, based on the given parameter.

- Category 2: 1≤ DS ≤10. The analytical results are greater than the criterion, but less than 10 times the criterion.

- Category 3: DS >10. The analytical results are greater than 10 times the criterion. The concentration of the given parameter in the leachate is significantly in excess of the relevant criterion.

These three categories provide a ready means of assessing the relative importance of the various leachate constituents. The boundary between categories 2 and 3 is set at DS = 10. The selection of the factor 10 is a matter of convenience. It serves to separate those constituents which are somewhat elevated from those which are substantially above their respective water quality criteria.

The remainder of this section is a discussion of the comparison between the observed concentrations and the various groups of water quality criteria. Category 3 parameters are discussed in detail, and more information is given on the specific part of the study in which the associated leachates are generated. It must be reiterated that the data base upon which this analysis is made is preliminary and is likely to change substantially during refinement and regeneration before the conclusion of the program.

COMPARISON WITH NATIONAL INTERIM PRIMARY AND SECONDARY DRINKING WATER REGULATIONS

The Safe Drinking Water Act seeks to protect drinking water supplies by establishing national primary and secondary standards as maximum contaminant levels (mcl). The primary mcls[9] are established to protect human health; the secondary mcls[10] serve to ensure the aesthetic quality of water supplies.

The analytical results of Tables 24, 25 and 26 were compared to the mcls for inorganic constituents established in both the National Interim Primary Drinking Water Regulations (NIPDWR) and the National Secondary Drinking Water Regulations (NSDWR). A discharge severity was calculated, and the results are summarized in Table 27.

Table 27 indicates that, on the basis of laboratory studies, cadmium is the species of greatest probable concern for PFBC waste leachates. On the basis of field studies, the species of interest are manganese, sulfate and total dissolved solids.

The cadmium concentration in step 1 leachate is at or below the detection limit of 0.005 mg/ℓ, but after interaction with the disposal media in step 4, the cadmium concentrations were 0.19 mg/ℓ for shale and 0.2 mg/ℓ for limestone. In comparison with the primary drinking water maximum contaminant level (mcl) of 0.010 mg/ℓ, the step 4 leachate with shale has a discharge severity of 19; with limestone, the DS is 2. Step 4 leachate for the other four media remained at or below 0.005 mg/ℓ. Leachates from the field cells all have volume-weighted concentrations of less than the Cd mcl.

Although manganese concentrations in laboratory studies exceeded the 0.05 mg/ℓ maximum contaminant limit set by the secondary drinking water regulations for two of the disposal media (shale and alluvium) the concentrations were less than a factor of ten greater than the limit. The volume-weighted average manganese concentrations in leachates from the upper sample points of the field cells range from 0.6 to 3.1 mg/ℓ. All of these values exceed the 0.05 mg/ℓ limit by more than a factor of 10. Volume-weighted average leachate concentrations of manganese from the lower sampling points range from 0.75 to 22.1 mg/ℓ, all of which are more than 10 times the limit. Volume-weighted average manganese concentrations in leachate from the control field cells are 0.43 and 0.9 for the shale and alluvium cells, respectively.

Sulfate concentrations in leachates generated in laboratory studies generally exceed the 250 mg/ℓ maximum contaminant limit set in the secondary drinking water regulations, but the excess is not as high as a factor of 10.

TABLE 27. SUMMARY OF DISCHARGE SEVERITY FOR PARAMETERS IN DRINKING WATER REGULATIONS

Category 1 Parameters
(DS <1)

Laboratory Leachate		Field Cell Leachate**	
Generation	**Attenuation**	**Generation**	**Attenuation**
As, Ba, Cd, Cl, Cu, F, Fe, Pb, Mn, Hg, Ag, Zn	Ba, Cl, Cu, F, Hg, Zn	Ba, Cd, Cl, Cu, F, Ag, Zn	Ba, Cd, Cu, F, Fe, Ag, Zn

Category 2 Parameters
(1< DS <10)

Laboratory Leachate		Field Cell Leachate	
Generation	**Attenuation**	**Generation**	**Attenuation**
Cr, Se, SO_4, TDS	As,* Cr, Fe, Pb,* Mn, Se,* Ag, SO_4, TDS	Cr, Fe	Cl, Ca

Category 3 Parameters
(DS >10)

Laboratory Leachate		Field Cell Leachate	
Generation	**Attenuation**	**Generation**	**Attenuation**
	Cd	Mn, SO_4, TDS	Mn, SO_4, TDS

*Tabular postion determined by detection limit.
**As, Pb, Hg, Se not determined for field cell leachates.

Leachate samples from the upper sample point of the field cells all have sulfate concentrations greater than 10 times the 250 mg/ℓ mcl. Although the concentrations are less for leachates from the lower sample point, they are still higher than 10 times the mcl for the shale, sandstone and limestone cells. In the control cells, the sulfate concentrations exceed the mcl, but not by a factor as high as 10.

The total dissolved solids content of Step 1 leachate is over 3,200 mg/ℓ, and the concentration of TDS after leachate exposure to the disposal media ranges from 1,055 to 2,040 mg/ℓ. All of these values exceed the secondary drinking water maximum contaminant limit of 500 mg/ℓ, but not by as much as a factor of 10. In the field cells, the volume-weighted average TDS content of upper sample point leachates is very high, ranging from 9,820 to 15,300 mg/ℓ. All of these values are much higher than 10 times the 500 mg/ℓ mcl. Lower sample point volume-weighted average leachate TDS are lower (ranging from 1,340 to 14,100 mg/ℓ) but are still in excess of 10 times the limit for shale, sandstone and limestone. The control cell leachate volume-weighted average TDS content is lower (250 mg/ℓ for the alluvium cell and 3,780 mg/ℓ for the shale cell).

COMPARISON WITH MULTIMEDIA ENVIRONMENTAL GOALS

Multimedia Environmental Goals (MEG's) are levels of contaminants or degradents (in ambient air, water, or land or in emissions or effluents conveyed to ambient media) that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology.

To date a total of 650 chemical substances and physical agents (e.g., noise, heat), nearly all of which are expected to be associated with fossil fuel processes, have been selected as part of a "Master List" for which MEG's are to be established. The MEG's have already been established for 216 substances on the Master List. The MEG values(s) for a given substance may be based on several or all of the 12 criteria shown in Table 28. These criteria

TABLE 28. MEG VALUE BASES FOR EMISSION AND AMBIENT LEVEL GOALS

Goal	Category	MEG Value Basis
Emission Level Goals (Air, Water, Land)	Existing Standards	NSPS, BAT, BPT
	Developing Technology	Engineering Estimates
	Discharge Severity	Health Effects Ecological Effects
	Ambient Level Goal	Health Effects Ecological Effects
	Elimination of Discharge	Natural Background Level
Ambient Level Goals (Air, Water, Land)	Current or Proposed Ambient Standards on Criteria	Health Effects Ecological Effects
	Toxicity Based Ambient Severity (AS)	Health Effects Ecological Effects
	Zero Threshold Pollutants (AS)	Health Effects

NSPS: New Source Performance Standard
BAT: Best Available Technology
BPT: Best Practable Technology

cover emission level and ambient level goals. Depending on the data available, up to 12 MEG values may be generated for a given substance for each medium (air, water and land). One of the MEG criteria which is most currently used in environmental assessment work is the discharge MEG (DMEG). DMEG is the approximate concentration for contaminants in source emissions which may not evoke significant harmful or irreversible responses in exposed humans or ecology, when those exposures are limited to short durations (less than 8 hours per day).

Most of the MEG's are derived through models which translate toxicological data, recommended concentration levels, and federal standards or criteria into emission or ambient level goals. For most of the categories listed in Table 28, more than one model is available for obtaining the ambient MEG values (AMEG). Where different AMEG values can be obtained by using different models, one with the lowest value is chosen as the MEG value. Models used to calculate MEG values can be found in the Multimedia Environmental Goals.[8]

The data in Tables 24 to 26 were compared with available DMEG values (lower of health or ecology limit) and a discharge severity calculated. Results of this comparison are presented in Table 29.

Table 29 indicates that, on the basis of laboratory studies, the elements of greatest probable concern are calcium, cadmium, cobalt, nickel, potassium and silver. On the basis of the field studies, the elements of interest are calcium, manganese, nickel and potassium. Each species is discussed below.

The calcium concentration in step 1 leachate was 1,700 mg/ℓ. In comparison with the DMEG value for ecology (16 mg/ℓ), this leachate has a discharge severity of 106. Values for the attenuation phase of the laboratory studies are somewhat lower, ranging from 500-1,000 mg/ℓ, but still more than 10 times the DMEG value. The volume-weighted average calcium concentration in leachates from all sample points in the field cells exceeds the DMEG value. At

TABLE 29. SUMMARY OF DISCHARGE SEVERITY FOR DMEG VALUES

Category 1 Parameters
(DS <1)

Laboratory Leachate		Field Cell Leachate**	
Generation	Attenuation	Generation	Attenuation
Al, As, Ba, B, Cr, Co, Cu, Pb, Li, Mg, Mn, Hg, Mo,† [illegible], Se, Ag, Sr, Ti, V	Ba, B, Cr, Li, Mg, Hg, Sr, Ti, U††	Al, Ba, Bx, Cr, Co, Cu, Mo, Sr, Ti, Zn	Al, Ba, Bx, Cr, Cu, Mo, Sr, Ti

Category 2 Parameters
(1< DS <10)

Laboratory Leachate		Field Cell Leachate	
Generation	Attenuation	Generation	Attenuation
Cd,* Ni,* Zn	Al, As,* Cu, Pb,* Mn, Se,* V, Zn	Cd,* Li, Mg, Ag, V	Cd,* Co, Li, Mg, Ag, V, Zn

Category 3 Parameters
(DS >10)

Laboratory Leachate		Field Cell Leachate	
Generation	Attenuation	Generation	Attenuation
Ca	Ca, Cd, Co, Ni, K, Ag	Ca, Mn, Ni, K	Ca, Mn, Ni, K

*Tabular position determined by detection limit.
**As, Pb, Hg, Se, U not determined for field cell leachates
†Mo not determined for laboratory attenuation.
††U not determined for laboratory generation.

all points except the lower sample point in the alluvium cell and the alluvium control, the concentration is greater than 10 times the DMEG value.

Cadmium concentrations in Step 1 leachate were below the detection limit of 0.005 mg/ℓ, but after interaction with the disposal media in Step 4, the concentrations rose to 0.19 mg/ℓ for shale and 0.02 mg/ℓ for limestone. Both of these values are more than 10 times the DMEG value for ecology (0.001 mg/ℓ). In leachates from the upper sampling point of the field cells, the DMEG limit was exceeded but not by as much as a factor of 10. Cadmium concentrations in leachates from the lower sample point all fell at or below the instrument detection limit. Volume-weighted average concentrations of cadmium in leachates from the control field cells were at or near the analytical detection limit.

Cobalt was found to be below the detection limit in the leachate generation phase of laboratory studies, but it exceeded the DMEG ecology limit of 0.25 mg/ℓ after exposure to all the disposal media except shale and interburden. For the limestone media, the maximum cobalt concentration was 2.8 mg/ℓ, which is more than 10 times the limit. Maximum concentrations after exposure to other disposal media were less than 10 times the limit. In field cell leachates cobalt concentrations generally did not exceed the 0.25 mg/ℓ limit, and none of them exceeded the limit by as much as a factor of 10. The control field cells had leachate concentrations below the 0.25 mg/ℓ limit.

The concentration of nickel in the Step 1 leachate was below the 0.0124 mg/ℓ detection limit, but concentrations after exposure to the disposal media were more than 10 times the DMEG value for ecology (0.01 mg/ℓ) for all disposal media except interburden. The field studies also disclosed a potential problem of excessive concentrations of nickel; all leachates from both the upper and lower sample points had volume-weighted average nickel concentrations in excess of 10 times the DMEG value for ecology with the exception of alluvium. However, the nickel value for the shale control field cell also exceeded the DMEG value by more than a factor of ten. For the field control cells, the volume-weighted average leachate concentrations for nickel exceed the DMEG value by a factor of 3 in the alluvium cell and a factor of 13 in the shale cell.

The DMEG value (ecology) for silver is 0.005 mg/ℓ. Silver concentrations in laboratory generated leachates are at or below the analytical detection limit of 0.005 mg/ℓ, but rise after contact with all media except shale. The maximum observed concentration is 0.175 in the limestone-contacted leachate. Leachate contacted with alluvium and glacial till also exceed the DMEG value by more than a factor of 10. Field cell observations are all less than 10 times the DMEG value.

All of the field leachate volume-weighted average concentrations of manganese exceed the DMEG value (ecology) of 0.10 mg/ℓ. For leachate generation (upper sample point), the observations range from 0.6 mg/ℓ in the limestone cell to 3.1 mg/ℓ in shale cell No. 2. Manganese concentration in the shale and glacial till cells are more than 10 times the DMEG. For the lower sample point, the range is 0.75 mg/ℓ (limestone) to 22.1 (sandstone). Leachate from shale, sandstone and alluvium all display a discharge severity greater than 10. Leachates from the control cells exceed the criterion, but not by as much as a factor of 10.

Potassium concentrations in Step 1 leachates apparently are below the 23 mg/ℓ DMEG limit for ecology. The concentrations for Step 4 leachates range up to about 850 mg/ℓ, and five of the six disposal media exceed the limit by more than a factor of 10. In the field cells, volume-weighted average potassium concentrations in leachates from the upper sample point range from 490 to 930 mg/ℓ for all disposal media. These values are all well over 10 times the DMEG limit for ecology. The volume-weighted average concentrations in leachates from the lower sample point are lower (ranging from 104 to 410 mg/ℓ) but are still generally greater than 10 times the ecology limit. Leachate from the control cells also exceed the ecology limit but not by as much as a factor of 10.

COMPARISON WITH QUALITY CRITERIA FOR WATER (QCW)

Quality Criteria for Water[13] addresses the effects of those basic water constituents and pollutants that are considered most significant in the aquatic environment. Criteria levels are recommended for a water quality that will provide for the protection and propogation of fish and other aquatic life and for recreation in and on the water. Criteria are also presented for domestic water supply. Water quality criteria do not have direct regulatory use, but they form the basis for judgment in several EPA programs that are associated with water quality considerations.

Recommended criteria for many of the parameters for this program are the same as the maximum contaminant levels specified in the Drinking Water Regulations presented previously. Only contaminants for which the criteria differ from the regulations, mercury and boron, are discussed below.

Quality Criteria for Water recommends a maximum permissible mercury concentration of 0.00005 mg/ℓ for protection of freshwater aquatic life. The most sensitive method for mercury determination is the atomic absorption cold vapor technique. However, the detection limit is 0.0005 mg/ℓ, a factor of 10 above the criterion. Therefore, no valid comparisons can be made between the criterion for freshwater aquatic life and concentrations in the FBC leachates.

For long term irrigation of sensitive crops, the QCW criterion for boron is 0.75 mg/ℓ. Boron was found to be of particular concern in the leachate generation phase (Step 1) of laboratory studies because the concentration is over 13.0 mg/ℓ, which is more than 10 times the recommended limit of 0.75 mg/ℓ for irrigation water supplies. After exposure to the disposal media in Step 4, however, the boron concentrations generally fell near or below the 0.75 mg/ℓ value. In the leachate generation sample point (upper sample point) of the field cells, the volume-weighted average boron concentration reached 11.1 mg/ℓ in one field cell and 11.5 mg/ℓ in another. At the leachate attenuation sample point (lower sample point), the volume weighted average boron concentrations were less but still reached a maximum of 6.84 mg/ℓ in the limestone field cell. Leachates from the control field cells had boron concentrations well within the 0.75 mg/ℓ limit.

SECTION 6

FUTURE PROGRAM EFFORTS

This section summarizes the activities that remain to be accomplished in the program, as set forth in Section 2. The discussion presents the general nature of the future work efforts, taking into account the most recent program approach.

INFORMATION SERVICES

The library will be providing the services indicated in Section 2 of this report. The current awareness services available through Lockheed Retrieval Service may be expanded, and additional searches on particular topics may also be made (e.g., field cells, shake tests, etc.).

WASTE ACQUISITION

Two AFBC wastes are to be obtained in the first quarter of 1980 for laboratory and field testing in this program. These wastes are from the EPRI/B&W 6' x 6' AFBC test unit and the Georgetown University 100,000 lb steam/hr institutional AFBC. Both of these boilers are to operate with an elutriated solids recycle for increased combustion efficiency, increased sulfur capture, and reduced nitrogen oxides.

As of 1 January 1980, the EPRI/B&W 6' x 6' is being modified. Two of the modifications are important in making the waste from this unit representative of wastes anticipated from major sources in the future. These modifications are the addition of a baghouse for final particulate collection and increasing the recycle capacity of the solids caught in the cyclone. The in-bed tube bundle is also being changed during this modification. The modifications are scheduled to be completed, and hot, non-recycle operation should start in late January with recycle operation scheduled for mid-February.

The timing of the Georgetown University AFBC boiler waste availability is more difficult to judge, although acceptable operation for this program appears to be approaching. The boiler has fired coal intermittently for six months, but the solids recycle has been hampered by the operation of the solids eductors. A material balance to determine the combustion efficiency has yet to be performed. Progress is being monitored, and the waste will be obtained as soon as possible.

FUTURE LABORATORY STUDIES

To date, the laboratory studies task has included the investigation of the leachability of the mixed PFBC waste and the attenuation capacities of the six disposal media for leachate contaminants from the PFBC waste. These studies have been complemented by various physical characterizations of the waste and the media. Future efforts in this investigation will include:

- determination of pertinent chemical and physical characteristics of additional FBC wastes,
- further study of attenuation capacity of the six disposal media, and
- compatability testing of liners for interaction with PFBC leachate.

Waste Characterization

The full batch equilibration protocol (leachate generation and attenuation) described in Section 3 will be carried out with two AFBC wastes. The FBC wastes will be physically characterized by x-ray diffraction analysis, scanning electron microscopy, electron microprobe analysis, specific gravity analysis, and surface area analysis.

Disposal Media Characterization

All of the proposed physical studies of disposal media are complete, with the exception of the determination of the anion exchange capacities of the media. Because the laboratory leaching results indicate that alkaline conditions prevail at equilibrium, the normally predominant cation exchange capacities may be overshadowed by the chemical interaction between soluble anions and the disposal media.

Further investigation of the attenuation capacity of each disposal medium will be carried out with leachates from two AFBC wastes to determine primary and secondary attenuation effects through the batch equilibration protocol.

Liner Compatability Studies

Liner compatability studies will be performed as outlined in Section 2. The chemical integrity and physical surface changes of six synthetic liners and a clay (bentonite) liner will be studied to determine long-term behavior. The tensile strength of the synthetic liners will be monitored periodically along with the total organic carbon content of the leachate and the physical surface changes. The clay will be subjected to x-ray analysis and SEM investigation periodically.

FIELD STUDIES

The remaining work to be accomplished for the field studies task includes completion of the test matrix, continued operation and sampling of the field cells, conduct of the large permeameter experiment, and post-operational sampling of the wastes and disposal media in the field cells.

Completion of Test Matrix

The major future effort in the field studies task is completion of the remaining nine field cells at the Crown facility. All are filled through the upper sand layer (see Figure 7) and covered, awaiting availability of suitable FBC wastes. Present plans call for four of the cells to be filled with Georgetown AFBC recycle wastes and five cells to be filled with EPRI/B&W 6' x 6' AFBC recycle wastes as shown in Table 4. It is anticipated that samples of both of these wastes will be shipped to Crown in early 1980. All nine remaining cells will be completed in the same manner as the first eight were. The addition of a third sample point between the upper disposal medium and waste is under consideration. After the cells are completed, an initial irrigation will be applied, the cells placed in operation, and the sample schedule will be initiated.

Large Permeameter Experiment

The long-term behavior of FBC wastes in a landfill environment is largely unknown. There exists a reasonable probability that the hydraulic properties of FBC wastes will change over time. The curing process is expected to produce a relatively indurated mass which will then be subjected to chemical and mechanical weathering. The waste mass may fracture or "fissure" or develop solution openings. The extent of induration and development of secondary permeability may well depend on disposal product handling and time since emplacement.

Two large permeameter cells are to be emplaced at the Crown field site in order to experimentally measure the permeability of the waste mass. The permeability of the fresh waste mass will be measured initially, and the cells will then be left exposed to the local climate for the duration of the field studies. At the close of the field studies, the permeability of the waste mass will again be measured and the waste exhumed for a visual examination. Permeability will be measured by the field crust test method.* The two permeameters will be replicates, except that one waste will be emplaced without first slaking the lime.

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*The crust test method for in-situ measurement of saturated and unsaturated hydraulic conductivity.[14]

In many ways, the large permeameters will be analogues of the field cells previously described. The shells will be 48-inch inside-diameter sections of reinforced concrete pipe, but only 4 feet high. In order to maintain unsaturated conditions, they will be set on a "pad" of concrete blocks (ungrouted) and the lower end will be lined with filter fabric. A 30-inch lift of waste, bounded above and below by a 6-inch lift of silica sand, will be emplaced in each. A 6-inch freeboard will prevent surface runoff. In order to fully expose the wastes to seasonal temperature variations, and thus accelerate weathering, the permeameters will be installed above ground. The shells for the experiment are already in place.

Solid Phase Sampling

At the close of the field studies, the field cells are to be abandoned in place or exhumed, and thus may prudently be subjected to destructive sampling. Full length, 4-inch diameter cores will be collected from three field cells at the conclusion of the field studies. The method of choice is to use a drop hammer to advance a Shelby or other thin wall soil tube sampler, and recover sequential tube samples through the full length of the cell. Based on sampling history, the three cells most likely to yield interesting and useful results will be selected.

The cores will be analyzed both chemically and physically to determine the location and state of solid-phase contamination and the physical condition of the waste body. The chemical and physical analyses will be a repeat of the pre-experiment solid phase tests, as shown below:

- x-ray diffraction analysis,
- scanning electron microscopy,
- surface area analysis,
- ion exchange capacity, and
- whole-sample chemical analysis

FUTURE CHEMICAL ANALYSES

Although approximately 13,000 analyses have been performed to date, this effort represents only a fraction of the total program analyses. Additional efforts include:

- whole-sample chemical analysis of all FBC wastes and attenuation media,
- chemical analysis of leachate solids,
- chemical analysis for special studies, and
- chemical analysis of field and laboratory protocol leachates.

The evaluation of the PFBC leachate in laboratory and field studies can be enhanced by further testing to define accuracy for low concentration levels. The method of verifying the leaching data will consist of analysis of solids both before and after leaching to provide a mass balance for components. This approach will verify the credibility of the leaching and attenuation results.

Chemical Analysis of FBC Wastes and Attenuation Media

Chemical analysis of raw wastes and media will provide information to document the composition of materials tested. This documentation will provide a reference for comparison with future wastes. Analyses planned for solids include:

- ultimate and proximate analyses--these analyses define heat content (Btu/lb), carbon, hydrogen, nitrogen, chlorine, oxygen, sulfur, and ash content of solid samples.
- spark source mass spectrometry analysis--SSMS analysis will provide a survey of concentrations of approximately 70 elements.

- quantitative chemical analysis--the concentration of parameters included in leachate monitoring will be quantified for solids.

Chemical Analysis of Leached Solids

Additional solids to be tested include leached material from laboratory and field studies. Wastes from Step 2 (repetitive contact with deionized water) will be analyzed to define the amount of materials leached. Also, media from Step 5 (repetitive contact with fresh leachate) will be analyzed to define the change (increase or decrease) of parameters indicative of media attenuation or media contribution. Core samples from three field cells after the monitoring period is terminated will be collected and analyzed.

Chemical Analysis for Species Studies

Special studies will be conducted to provide additional validation and comparative information. These studies include:

- Additional Laboratory Protocol Studies. An additional step to the laboratory protocol consists of contact of burdened media with deionized water to show leachability of parameters from burdened media if exposed to direct rainfall in the future.

- Analysis of Leachates from Liner Compatability Studies. Polymeric liners may degrade with time when exposed to FBC leachate. Total organic carbon (TOC) content of the leachate will be monitored during the study to identify liner decomposition. Also, to test decomposition of the sodium bentonite liner material, aluminum content of the leachate will be monitored.

- Analysis of Top Cover Media Leachates in Field Cells. Future field cells may have an additional sampling array positioned beneath the upper media to define the composition of moisture as it enters the waste. Samples from this array would be analyzed in the same manner and for the same parameters as other field leachates.

Chemical Analysis of Leachates

Leachates from both laboratory and field experiments will continue to be analyzed. No major changes in parameters are anticiapted for future leaching studies. The parameter list has been selected with flexibility to ensure important species are not overlooked. No major changes are indicated on the basis of PFBC waste and disposl media leachate analyses conducted to date. However, as noted in Section 2, screening of the initial FBC laboratory leachate may prove to be insufficient to define all parameters of interest in early field cell leachate. Therefore, the initial field cell leachates will also be analyzed for certain parameters that likely will not be carried through all analyses. Some of the paramters in the initial analyses that are not detected will be deleted from further analysis requirements.

DATA MANAGEMENT AND INTERPRETATION

No major changes in the procedures for analyzing the chemical data are foreseen for the duration of the program. The chemical analytical and other data from laboratory and field studies will be input to the data management system as before. The SAS data management system will continue to be used to perform the necessary statistical and other data processing analyses and to generate the required data graphics. Efforts will be continued to establish an empirical but statistically validated correlation between the results of laboratory and field studies. This correlation, as noted, is expected to be fundamental to the development of the conceptual model for application on a case-by-case basis to individual future FBC waste disposal sites.

CONCEPTUAL MODEL DEVELOPMENT

Most of the work for the development of the conceptual model for case-by-case application remains to be accomplished. The efforts for this task have been held largely in abeyance pending the successful establishment of a correlation between laboratory and field studies. Work thus far has been limited to compilation of the results of previous similar efforts from the published literature and other sources. Most of the efforts for this task will be performed during the second year of the program.

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APPENDIX I

LABORATORY AND FIELD CHEMICAL ANALYTICAL DATA LIST

A significant volume of analytical data has been generated in this program, both from the execution of the laboratory protocol and the operation and sampling of the field cells. This appendix presents a listing of the analytical data obtained and entered into the data management system as of 6 December 1979. A data management system has been implemented to handle this large volume of data, and it was used to compile this appendix. These data are all for the PFBC waste, and are therefore less than one-third of that expected by the end of the program. All data presented are in mg/ℓ except for the pH, TOC, TDS, and conductivity values.

The laboratory batch equlibration data are presented first. The majority of the batch laboratory tests were conducted (or equilibrated) for seven days, but one- and two-day tests were also conducted to provide insight into kinetic effects that are to be used in relating laboratory and field results. The results from the seven-day tests are presented first, followed by two-day and then one-day equilibration results. The component concentrations and other analytical parameters are listed by protocol step number. The protocol steps are explained in Section 3 of the report. For each set of one-, two-, and seven-day results, the leachate generation values are presented first (Protocol Steps 1, 2, and 3), followed by the leachate attenuation observed with each of the six disposal media (Protocol Steps 4 to 7). Table A-1 presents a detailed guide to the laboratory data. It should be noted that for both the laboratory and field data, a negative value means the measured concentration was below the detection limit, and the numerical entry is the detection limit.

A complete listing of the analytical data from the field cells is presented following the laboratory data. These data are arranged by chemical parameters, and are listed chronologically for each field cell. Two sample points are in each cell, an upper point below the PFBC waste and a lower point below the disposal medium. The values from the two different sample points are distinguished by either a U or an L in the SAMPT column. Sample collections from both the upper and lower sample points are made on the same day.

TABLE A-1. PRESENTATION ORGANIZATION FOR LABORATORY ANALYTICAL RESULTS

- Seven-Day Batch Equilibration:
  - Leachate Concentrations (Protocol Steps 1, 2, and 3)
  - Attenuation by Shale (Protocol Steps 4 to 7)
  - Attenuation by Sandstone (Protocol Steps 4 to 7)
  - Attenuation by Alluvium (Protocol Steps 4 to 7)
  - Attenuation by Glacial Till (Protocol Steps 4 to 7)
  - Attenuation by Limestone (Protocol Steps 4 to 7)
  - Attenuation by Interburden (Protocol Steps 4 to 7)
- Two-Day Batch Equilibrium:
  - Leachate Concentrations (Protocol Steps 1, 2, and 3)
  - Attenuation by Shale (Protocol Steps 4 to 7)
  - Attenuation by Sandstone (Protocol Steps 4 to 7)
  - Attenuation by Alluvium (Protocol Steps 4 to 7)
  - Attenuation by Glacial Till (Protocol Steps 4 to 7)
  - Attenuation by Limestone (Protocol Steps 4 to 7)
  - Attenuation by Interburden (Protocol Steps 4 to 7)
- One-Day Batch Equilibrium:
  - Leachate Concentrations (Protocol Step 1)
  - Attenuation by Shale (Protocol Step 4)
  - Attenuation by Sandstone (Protocol Step 4)
  - Attenuation by Alluvium (Protocol Step 4)
  - Attenuation by Glacial Till (Protocol Step 4)
  - Attenuation by Limestone (Protocol Step 4)
  - Attenuation by Interburden (Protocol Step 4)

LABORATORY DATA LISTING

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1) 0.464(2) 0.855(3) 0.957(4) 1.23(5) 1.38(6) 2.23(7)	0.493(1) 0.369(2)	0.174 (1)	0.673(1) 0.753(2) 2.05(3) 2.23(4) 4.6(5) 4.81(6)	1.82 (1)
ARSENIC	0.04 (0)	0.04(1) 0.04(2) 0.04(3) 0.04(4) 0.04(5) 0.04(6) 0.04(7)	0.04(1) 0.04(2)	0.04 (1)	.(1) .(2) 0.364(3) 0.55(4) 0.285(5) 0.4(6)	0.04 (1)
BARIUM	0.171 (0)	0.114(1) 0.113(2) 0.0824(3) 0.073(4) 0.0482(5) 0.0443(6) 0.0474(7)	0.321(1) 0.281(2)	0.221 (1)	0.206(1) 0.199(2) 0.135(3) 0.0832(4) 0.0245(5) 0.0194(6)	0.0242 (1)
BORON	13.3 (0)	8.54(1) 17.3(2) 6.46(3) 2.97(4) 2.03(5) 1.57(6) 1.54(7)	22.6(1) 27.5(2)	0.399 (1)	0.469(1) 0.658(2) 0.726(3) 0.618(4) 1.09(5) 0.884(6)	0.002 (1)
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.195 (1)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6)	0.0025 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1270(1)	1790(1)	505 (1)	836(1)	376 (1)
		1630(2)	1660(2)		970(2)	
		894(3)			579(3)	
		629(4)			559(4)	
		559(5)			68.5(5)	
		512(6)			53.4(6)	
		593(7)				
CHROMIUM	0.0622 (0)	0.127(1)	0.2(1)	0.0355 (1)	0.0396(1)	0.215 (1)
		0.058(2)	0.318(2)		0.0491(2)	
		0.0025(3)			0.0294(3)	
		0.0025(4)			0.0298(4)	
		0.0025(5)			0.0124(5)	
		0.0025(6)			0.0025(6)	
		0.0025(7)				
CL	4.46 (0)	1.27(1)	15(1)	10 (1)	.(1)	. (1)
		1.95(2)	22.5(2)		.(2)	
		0.5(3)			.(3)	
		0.5(4)			.(4)	
		.(5)			.(5)	
		2.5(6)			.(6)	
		.(7)				
COBALT	0.075 (0)	0.075(1)	0.075(1)	0.075 (1)	0.967(1)	0.075 (1)
		0.075(2)	0.075(2)		1.19(2)	
		0.075(3)			0.65(3)	
		0.075(4)			0.475(4)	
		0.075(5)			0.075(5)	
		0.075(6)			0.075(6)	
		0.075(7)				
COND	9530 (0)	6000(1)	9000(1)	2410 (1)	4030(1)	. (1)
		4600(2)	9500(2)		5130(2)	
		4150(3)			5450(3)	
		3350(4)			5950(4)	
		2570(5)			6530(5)	
		2700(6)			6330(6)	
		2110(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0412(1) 0.0025(2)	0.172 (1)	0.0618(1) 0.0734(2) 0.0393(3) 0.0285(4) 0.0103(5) .00477(6)	0.0025 (1)
F	0.785 (0)	2.32(1) 1.24(2) 0.44(3) 0.49(4) .(5) 0.405(6) .(7)	2.22(1) 0.775(2)	0.415 (1)	0.28(1) 0.355(2) 0.28(3) 0.285(4) 0.375(5) 0.4(6)	. (1)
IRON	0.224 (0)	0.267(1) 0.181(2) 0.115(3) 0.052(4) 0.0925(5) 0.0714(6) 0.125(7)	0.198(1) 0.154(2)	0.418 (1)	0.153(1) 0.0319(2) 0.0473(3) 0.102(4) 0.0303(5) 0.651(6)	0.335 (1)
LEAD	0.035 (0)	0.035(1) 0.035(2) 0.035(3) 0.035(4) 0.035(5) 0.035(6) 0.035(7)	0.035(1) 0.035(2)	0.035 (1)	.(1) .(2) 0.035(3) 0.0837(4) 0.035(5) 0.035(6)	0.035 (1)
LITHIUM	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	0.005 (1)	0.005(1) 0.005(2) 0.02(3) 0.03(4) .(5) .(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1) 0.698(2) 0.888(3) 0.106(4) 0.305(5) 0.226(6) 0.319(7)	1.08(1) 0.425(2)	0.0797 (1)	.00395(1) .00105(2) 0.0126(3) 0.0168(4) 0.214(5) 0.017(6)	0.161 (1)
MANGANESE	.00103 (0)	500E-6(1) 500E-6(2) 500E-6(3) 500E-6(4) 500E-6(5) 500E-6(6) 500E-6(7)	500E-6(1) 500E-6(2)	0.194 (1)	0.0123(1) .00953(2) .00717(3) .00524(4) .00703(5) 0.0211(6)	500E-6 (1)
MERCURY	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	500E-6 (1)	500E-6(1) 500E-6(2) 500E-6(3) 500E-6(4) .(5) .(6)	. (1)
NICKEL	0.0143 (0)	0.01(1) 0.01(2) 0.0592(3) 0.01(4) 0.066(5) 0.01(6) 0.01(7)	0.01(1) 0.01(2)	0.186 (1)	0.168(1) 0.184(2) 0.104(3) 0.118(4) 0.01(5) 0.0236(6)	0.01 (1)
PH	11.8 (0)	12.2(1) 11.9(2) 11.8(3) 11.5(4) 11.3(5) 11.2(6) 11(7)	12.3(1) 12.2(2)	10.9 (1)	11.9(1) 12.1(2) 12.1(3) 12.1(4) 12.2(5) 12.3(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1) 20(2) 20(3) 20(4) 20(5) 20(6) 20(7)	20(1) 20(2)	48.5 (1)	406(1) 483(2) 265(3) 217(4) 20(5) 20(6)	20 (1)
SELENIUM	0.06 (0)	0.06(1) 0.06(2) 0.06(3) 0.06(4) 0.06(5) 0.06(6) 0.06(7)	0.06(1) 0.06(2)	0.0312 (1)	0.0025(1) 0.0025(2) 0.0312(3) 0.0312(4) 0.06(5) 0.06(6)	0.06 (1)
SILICON	0.669 (0)	0.772(1) 0.746(2) 1.45(3) 1.04(4) 1.67(5) 2.33(6) 3.38(7)	0.519(1) 0.422(2)	1.08 (1)	0.51(1) 0.448(2) 0.791(3) 0.706(4) 1.31(5) 1.2(6)	2.46 (1)
SILVER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.0025 (1)	0.054(1) 0.0701(2) 0.0403(3) 0.027(4) 0.0148(5) .00489(6)	0.0025 (1)
SODIUM	16.7 (0)	36.3(1) 47.4(2) 25.6(3) 2.5(4) 2.5(5) 2.5(6) 2.5(7)	44.7(1) 71.1(2)	17.2 (1)	2.5(1) 2.5(2) 2.5(3) 2.5(4) 5.22(5) 2.5(6)	24.9 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1) 1360(2) 1360(3) 1440(4) 1240(5) 1290(6) 1080(7)	1240(1) 1310(2)	723 (1)	910(1) 1020(2) 1080(3) 1100(4) 1060(5) 1150(6)	. (1)
STRONTIUM	2.93 (0)	1.98(1) 1.69(2) 1(3) 0.614(4) 0.479(5) 0.356(6) 0.378(7)	4.62(1) 4.33(2)	2.03 (1)	2.77(1) 2.68(2) 1.4(3) 1.35(4) 0.0851(5) 0.07(6)	1.26 (1)
TDS	3210 (0)	2490(1) 2280(2) 2750(3) 2500(4) 2270(5) 2140(6) 2290(7)	3630(1) 3380(2)	1300 (1)	2260(1) 2900(2) 2860(3) 3030(4) 3110(5) 3410(6)	. (1)
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2) 100E-5(3) 100E-5(4) 100F-5(5) 100E-5(6) 100E-5(7)	100E-5(1) 100E-5(2)	0.169 (1)	0.0389(1) 0.043(2) 0.025(3) 0.0253(4) .00201(5) 100E-5(6)	100E-5 (1)
TOC	1.1 (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	3.3 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SHALE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1) 0.15(2) 0.15(3) .(4) .(5) .(6) .(7)	0.15(1) 0.15(2)	0.15 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	0.15 (1)
VANADIUM	0.005 (0)	0.005(1) 0.005(2) 0.005(3) 0.005(4) 0.005(5) 0.005(6) 0.005(7)	0.005(1) 0.005(2)	0.16 (1)	0.081(1) 0.0946(2) 0.0521(3) 0.0372(4) 0.005(5) 0.005(6)	0.005 (1)
ZINC	0.171 (0)	0.0898(1) 0.232(2) 0.113(3) 0.0129(4) 0.0109(5) 0.0218(6) 100E-5(7)	0.206(1) 0.112(2)	0.222 (1)	.00867(1) 0.0101(2) 0.0123(3) .00952(4) .00316(5) 100E-5(6)	0.181 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
+ LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1)	0.493(1)	0.299 (1)	0.522(1)	1.68 (1)
		0.464(2)	0.369(2)		1.63(2)	4.89 (2)
		0.855(3)			1.61(3)	4.31 (3)
		0.957(4)			1.13(4)	6.8 (4)
		1.23(5)			1.28(5)	. (5)
		1.38(6)			0.633(6)	
		2.23(7)				
ARSENIC	0.04 (0)	0.04(1)	0.04(1)	0.04 (1)	.(1)	0.04 (1)
		0.04(2)	0.04(2)		.(2)	. (2)
		0.04(3)			0.411(3)	. (3)
		0.04(4)			0.509(4)	. (4)
		0.04(5)			0.311(5)	. (5)
		0.04(6)			0.366(6)	
		0.04(7)				
BARIUM	0.171 (0)	0.114(1)	0.321(1)	0.116 (1)	0.181(1)	0.105 (1)
		0.113(2)	0.281(2)		0.14(2)	0.0976 (2)
		0.0824(3)			0.0757(3)	0.122 (3)
		0.073(4)			0.11(4)	0.146 (4)
		0.0482(5)			0.032(5)	. (5)
		0.0443(6)			0.0974(6)	
		0.0474(7)				
BORON	13.3 (0)	8.54(1)	22.6(1)	0.462 (1)	2.04(1)	0.398 (1)
		17.3(2)	27.5(2)		1.94(2)	0.483 (2)
		6.46(3)			1.42(3)	0.728 (3)
		2.97(4)			1.85(4)	0.722 (4)
		2.03(5)			0.79(5)	. (5)
		1.57(6)			0.204(6)	
		1.54(7)				
CADMIUM	0.0025 (0)	0.0025(1)	0.0025(1)	0.0025 (1)	0.0025(1)	0.037 (1)
		0.0025(2)	0.0025(2)		0.0025(2)	0.184 (2)
		0.0025(3)			0.0025(3)	0.0358 (3)
		0.0025(4)			0.0025(4)	0.132 (4)
		0.0025(5)			0.0025(5)	. (5)
		0.0025(6)			0.0025(6)	
		0.0025(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY INTERBURDEN   LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1270(1) 1630(2) 894(3) 629(4) 559(5) 512(6) 593(7)	1790(1) 1660(2)	1000 (1)	925(1) 859(2) 510(3) 579(4) 47.6(5) 48(6)	766 (1) 204 (2) 479 (3) 337 (4) . (5)
CHROMIUM	0.0622 (0)	0.127(1) 0.058(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.2(1) 0.318(2)	0.051 (1)	0.032(1) 0.121(2) 0.0628(3) 0.0219(4) 0.0203(5) 0.0115(6)	0.114 (1) 0.351 (2) 0.112 (3) 0.27 (4) . (5)
CL	4.46 (0)	1.27(1) 1.95(2) 0.5(3) 0.5(4) .(5) 2.5(6) .(7)	15(1) 22.5(2)	9.6 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	1.52 (1) 0.54 (2) 0.85 (3) 1.17 (4) 1.68 (5)
COBALT	0.075 (0)	0.075(1) 0.075(2) 0.075(3) 0.075(4) 0.075(5) 0.075(6) 0.075(7)	0.075(1) 0.075(2)	0.236 (1)	0.760(1) 2.84(2) 1.48(3) 0.533(4) 0.075(5) 0.075(6)	2.22 (1) 8.43 (2) 3.33 (3) 7.08 (4) . (5)
COND	9530 (0)	6000(1) 4600(2) 4150(3) 3350(4) 2570(5) 2700(6) 2110(7)	9000(1) 9500(2)	3470 (1)	4640(1) 5930(2) 6200(3) 6400(4) 6700(5) 6600(6)	2210 (1) 2320 (2) 2580 (3) 2790 (4) 3010 (5)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0412(1) 0.0025(2)	0.0133 (1)	0.045(1) 0.164(2) 0.0882(3) 0.0291(4) 0.0117(5) 0.0185(6)	0.128 (1) 0.524 (2) 0.771 (3) 1.15 (4) . (5)
F	0.785 (0)	2.32(1) 1.24(2) 0.44(3) 0.49(4) .(5) 0.405(6) .(7)	2.22(1) 0.775(2)	0.707 (1)	0.48(1) 0.455(2) 0.36(3) 0.385(4) 0.355(5) 0.44(6)	. (1) . (2) . (3) . (4) . (5)
IRON	0.224 (0)	0.267(1) 0.181(2) 0.115(3) 0.052(4) 0.0925(5) 0.0714(6) 0.125(7)	0.198(1) 0.154(2)	0.0548 (1)	0.012(1) 0.0831(2) 0.0419(3) 0.0137(4) .00779(5) 0.0787(6)	0.126 (1) 0.9 (2) 6.72 (3) 5.48 (4) . (5)
LEAD	0.035 (0)	0.035(1) 0.035(2) 0.035(3) 0.035(4) 0.035(5) 0.035(6) 0.035(7)	0.035(1) 0.035(2)	0.035 (1)	.(1) .(2) 0.035(3) 0.0544(4) 0.035(5) 0.035(6)	0.035 (1) . (2) . (3) . (4) . (5)
LITHIUM	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	0.005 (1)	0.005(1) 0.005(2) 0.03(3) 0.03(4) .(5) .(6)	0.0175 (1) 0.065 (2) 0.06 (3) 0.07 (4) . (5)

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* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1)	1.08(1)	0.027 (1)	.00165(1)	0.108 (1)
		0.698(2)	0.425(2)		800E-6(2)	1.29 (2)
		0.888(3)			.00588(3)	6.41 (3)
		0.106(4)			.00714(4)	6.14 (4)
		0.305(5)			0.0143(5)	. (5)
		0.226(6)			0.0214(6)	
		0.319(7)				
MANGANESE	.00103 (0)	500E-6(1)	500E-6(1)	.00237 (1)	0.0069(1)	0.0161 (1)
		500E-6(2)	500E-6(2)		0.0213(2)	0.323 (2)
		500E-6(3)			0.0126(3)	1.32 (3)
		500E-6(4)			.00467(4)	1.31 (4)
		500E-6(5)			.00198(5)	. (5)
		500E-6(6)			.00653(6)	
		500E-6(7)				
MERCURY	. (0)	.(1)	.(1)	500E-6 (1)	500E-6(1)	500E-6 (1)
		.(2)	.(2)		500E-6(2)	500E-6 (2)
		.(3)			500E-6(3)	500E-6 (3)
		.(4)			500E-6(4)	500E-6 (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				
NICKEL	0.0143 (0)	0.01(1)	0.01(1)	0.0698 (1)	0.166(1)	0.203 (1)
		0.01(2)	0.01(2)		0.324(2)	1.21 (2)
		0.0592(3)			0.172(3)	2.67 (3)
		0.01(4)			0.11(4)	3.05 (4)
		0.066(5)			0.01(5)	. (5)
		0.01(6)			0.01(6)	
		0.01(7)				
PH	11.8 (0)	12.2(1)	12.3(1)	11.6 (1)	11.9(1)	9.06 (1)
		11.9(2)	12.2(2)		12(2)	4.73 (2)
		11.8(3)			12.1(3)	4.06 (3)
		11.5(4)			12.1(4)	3.98 (4)
		11.3(5)			12.1(5)	3.88 (5)
		11.2(6)			12.4(6)	
		11(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1) 20(2) 20(3) 20(4) 20(5) 20(6) 20(7)	20(1) 20(2)	137 (1)	376(1) 866(2) 454(3) 231(4) 20(5) 20(6)	617 (1) 2080 (2) 652 (3) 1550 (4) . (5)
SELENIUM	0.06 (0)	0.06(1) 0.06(2) 0.06(3) 0.06(4) 0.06(5) 0.06(6) 0.06(7)	0.06(1) 0.06(2)	0.0312 (1)	0.0025(1) 0.0025(2) 0.0312(3) 0.0312(4) 0.06(5) 0.06(6)	0.0312 (1) 0.0025 (2) 0.0025 (3) 0.0025 (4) . (5)
SILICON	0.669 (0)	0.772(1) 0.746(2) 1.45(3) 1.04(4) 1.67(5) 2.33(6) 3.38(7)	0.519(1) 0.422(2)	1.09 (1)	0.444(1) 0.761(2) 1.19(3) 0.836(4) 1.49(5) 1.61(6)	3.21 (1) 6.54 (2) 28.3 (3) 27.7 (4) . (5)
SILVER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.013 (1)	0.043(1) 0.172(2) 0.0921(3) 0.0303(4) 0.021(5) 0.0186(6)	0.135 (1) 0.492 (2) 0.129 (3) 0.354 (4) . (5)
SODIUM	16.7 (0)	36.3(1) 47.4(2) 25.6(3) 2.5(4) 2.5(5) 2.5(6) 2.5(7)	44.7(1) 71.1(2)	13.2 (1)	2.5(1) 4.91(2) 3.88(3) 2.5(4) 4.48(5) 5.25(6)	14.1 (1) 14.8 (2) 4.11 (3) 10.4 (4) . (5)

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1)	1240(1)	1180 (1)	1080(1)	1330 (1)
		1360(2)	1310(2)		1110(2)	1390 (2)
		1360(3)			1150(3)	1560 (3)
		1440(4)			1180(4)	1800 (4)
		1240(5)			1110(5)	2000 (5)
		1290(6)			1210(6)	
		1080(7)				
STRONTIUM	2,93 (0)	1.98(1)	4,62(1)	2,85 (1)	2.83(1)	1,93 (1)
		1,69(2)	4,33(2)		2.02(2)	0.593 (2)
		1(3)			1.11(3)	1,88 (3)
		0,614(4)			1.38(4)	1,38 (4)
		0.479(5)			0,0867(5)	. (5)
		0,356(6)			0,097(6)	
		0,378(7)				
TDS	3210 (0)	2490(1)	3630(1)	2040 (1)	2650(1)	2250 (1)
		2280(2)	3380(2)		2760(2)	2350 (2)
		2750(3)			2960(3)	2640 (3)
		2500(4)			3060(4)	2790 (4)
		2270(5)			3260(5)	3560 (5)
		2140(6)			3430(6)	
		2290(7)				
TITANIUM	100E-5 (0)	100E-5(1)	100E-5(1)	0,0132 (1)	0.0364(1)	0,0512 (1)
		100E-5(2)	100E-5(2)		0.0768(2)	0.172 (2)
		100E-5(3)			0.0421(3)	0,0594 (3)
		100E-5(4)			0,0244(4)	0.131 (4)
		100E-5(5)			,00361(5)	. (5)
		100E-5(6)			100E-5(6)	
		100E-5(7)				
TOC	1.1 (0)	.(1)	.(1)	4,45 (1)	.(1)	. (1)
		.(2)	.(2)		.(2)	. (2)
		.(3)			.(3)	. (3)
		.(4)			.(4)	. (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1)	0.15(1)	0.15 (1)	.(1)	0.15 (1)
		0.15(2)	0.15(2)		.(2)	. (2)
		0.15(3)			.(3)	. (3)
		.(4)			.(4)	. (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				
VANADIUM	0.005 (0)	0.005(1)	0.005(1)	0.0249 (1)	0.0672(1)	0.173 (1)
		0.005(2)	0.005(2)		0.221(2)	0.643 (2)
		0.005(3)			0.114(3)	0.303 (3)
		0.005(4)			0.0432(4)	0.575 (4)
		0.005(5)			0.005(5)	. (5)
		0.005(6)			0.005(6)	
		0.005(7)				
ZINC	0.171 (0)	0.0898(1)	0.206(1)	0.0943 (1)	.00641(1)	0.107 (1)
		0.232(2)	0.112(2)		0.0326(2)	0.798 (2)
		0.113(3)			0.0185(3)	3.77 (3)
		0.0129(4)			.00611(4)	4.41 (4)
		0.0109(5)			0.0344(5)	. (5)
		0.0218(6)			0.578(6)	
		100E-5(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1) 0.464(2) 0.A55(3) 0.957(4) 1.23(5) 1.38(6) 2.23(7)	0.493(1) 0.369(2)	0.469 (1)	0.762(1) 1.11(2) 2.74(3) 2.46(4) 1.95(5) 0.797(6)	0.303 (1)
ARSENIC	0.04 (0)	0.04(1) 0.04(2) 0.04(3) 0.04(4) 0.04(5) 0.04(6) 0.04(7)	0.04(1) 0.04(2)	0.04 (1)	.(1) .(2) 0.451(3) 0.532(4) 0.407(5) 0.372(6)	0.04 (1)
BARIUM	0.171 (0)	0.114(1) 0.113(2) 0.0824(3) 0.073(4) 0.0482(5) 0.0443(6) 0.0474(7)	0.321(1) 0.281(2)	0.0954 (1)	0.234(1) 0.154(2) 0.109(3) 0.0772(4) 0.0458(5) 0.103(6)	0.0283 (1)
BORON	13.3 (0)	8.54(1) 17.3(2) 6.46(3) 2.97(4) 2.03(5) 1.57(6) 1.54(7)	22.6(1) 27.5(2)	0.139 (1)	0.827(1) 0.815(2) 0.977(3) 1.06(4) 0.997(5) 0.1(6)	0.002 (1)
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.0025 (1)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6)	0.0025 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1270(1) 1630(2) 894(3) 629(4) 559(5) 512(6) 593(7)	1790(1) 1660(2)	996 (1)	962(1) 974(2) 541(3) 520(4) 55.5(5) 32.4(6)	580 (1)
CHROMIUM	0.0622 (0)	0.127(1) 0.058(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.2(1) 0.318(2)	0.054 (1)	0.0419(1) 0.0847(2) 0.067(3) 0.0485(4) 0.0025(5) 0.0147(6)	0.135 (1)
CL	4.46 (0)	1.27(1) 1.95(2) 0.5(3) 0.5(4) .(5) 2.5(6) .(7)	15(1) 22.5(2)	9.45 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	. (1)
COBALT	0.075 (0)	0.075(1) 0.075(2) 0.075(3) 0.075(4) 0.075(5) 0.075(6) 0.075(7)	0.075(1) 0.075(2)	0.546 (1)	1.01(1) 1.96(2) 1.54(3) 1.14(4) 0.075(5) 0.075(6)	0.075 (1)
COND	9530 (0)	6000(1) 4600(2) 4150(3) 3350(4) 2570(5) 2700(6) 2110(7)	9000(1) 9500(2)	3590 (1)	4540(1) 5600(2) 7400(3) 7000(4) 6800(5) 6430(6)	. (1)

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1)	0.0412(1)	0.0316 (1)	0.0582(1)	0.0025 (1)
		0.0025(2)	0.0025(2)		0.111(2)	
		0.0025(3)			0.0886(3)	
		0.0025(4)			0.0664(4)	
		0.0025(5)			.00892(5)	
		0.0025(6)			0.0195(6)	
		0.0025(7)				
F	0.785 (0)	2.32(1)	2.22(1)	0.402 (1)	0.345(1)	. (1)
		1.24(2)	0.775(2)		0.375(2)	
		0.44(3)			0.34(3)	
		0.49(4)			0.42(4)	
		.(5)			0.37(5)	
		0.405(6)			0.365(6)	
		.(7)				
IRON	0.224 (0)	0.267(1)	0.198(1)	0.239 (1)	0.214(1)	0.203 (1)
		0.181(2)	0.154(2)		0.051(2)	
		0.115(3)			0.0673(3)	
		0.052(4)			0.103(4)	
		0.0925(5)			0.0206(5)	
		0.0714(6)			0.268(6)	
		0.125(7)				
LEAD	0.035 (0)	0.035(1)	0.035(1)	0.035 (1)	.(1)	0.035 (1)
		0.035(2)	0.035(2)		.(2)	
		0.035(3)			0.0564(3)	
		0.035(4)			0.102(4)	
		0.035(5)			0.0546(5)	
		0.035(6)			0.035(6)	
		0.035(7)				
LITHIUM	. (0)	.(1)	.(1)	0.005 (1)	0.005(1)	. (1)
		.(2)	.(2)		0.03(2)	
		.(3)			0.05(3)	
		.(4)			0.05(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1)	1.08(1)	0.0599 (1)	.00476(1)	0.0855 (1)
		0.698(2)	0.425(2)		920E-6(2)	
		0.888(3)			0.0108(3)	
		0.106(4)			0.0231(4)	
		0.305(5)			0.0534(5)	
		0.226(6)			0.204(6)	
		0.319(7)				
MANGANESE	.00103 (0)	500E-6(1)	500E-6(1)	0.0057 (1)	0.0124(1)	500E-6 (1)
		500E-6(2)	500E-6(2)		0.0155(2)	
		500E-6(3)			0.0121(3)	
		500E-6(4)			.00881(4)	
		500E-6(5)			500E-6(5)	
		500E-6(6)			.00412(6)	
		500E-6(7)				
MERCURY	. (0)	.(1)	.(1)	500E-6 (1)	500E-6(1)	. (1)
		.(2)	.(2)		500E-6(2)	
		.(3)			500E-6(3)	
		.(4)			500E-6(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				
NICKEL	0.0143 (0)	0.01(1)	0.01(1)	0.111 (1)	0.185(1)	0.01 (1)
		0.01(2)	0.01(2)		0.262(2)	
		0.0592(3)			0.176(3)	
		0.01(4)			0.19(4)	
		0.066(5)			0.01(5)	
		0.01(6)			0.01(6)	
		0.01(7)				
PH	11.8 (0)	12.2(1)	12.3(1)	11.9 (1)	12(1)	. (1)
		11.9(2)	12.2(2)		12.1(2)	
		11.8(3)			12.2(3)	
		11.5(4)			12.2(4)	
		11.3(5)			12.2(5)	
		11.2(6)			12.3(6)	
		11(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1) 20(2) 20(3) 20(4) 20(5) 20(6) 20(7)	20(1) 20(2)	217 (1)	431(1) 668(2) 475(3) 374(4) 20(5) 20(6)	20 (1)
SELENIUM	0.06 (0)	0.06(1) 0.06(2) 0.06(3) 0.06(4) 0.06(5) 0.06(6) 0.06(7)	0.06(1) 0.06(2)	0.0312 (1)	0.0025(1) 0.0025(2) 0.0312(3) 0.0312(4) 0.06(5) 0.06(6)	0.06 (1)
SILICON	0.669 (0)	0.772(1) 0.746(2) 1.45(3) 1.04(4) 1.67(5) 2.33(6) 3.38(7)	0.519(1) 0.422(2)	0.816 (1)	0.459(1) 0.539(2) 0.93(3) 0.666(4) 0.8(5) 0.981(6)	4.92 (1)
SILVER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.0325 (1)	0.0586(1) 0.117(2) 0.0933(3) 0.0703(4) 0.0163(5) 0.0187(6)	0.0025 (1)
SODIUM	16.7 (0)	36.3(1) 47.4(2) 25.6(3) 2.5(4) 2.5(5) 2.5(6) 2.5(7)	44.7(1) 71.1(2)	15.6 (1)	2.5(1) 3.98(2) 3.87(3) 3.38(4) 7.42(5) 6.51(6)	31.6 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1) 1360(2) 1360(3) 1440(4) 1240(5) 1290(6) 1080(7)	1240(1) 1310(2)	938 (1)	1010(1) 1090(2) 1080(3) 1180(4) 1160(5) 1220(6)	. (1)
STRONTIUM	2.93 (0)	1.98(1) 1.69(2) 1(3) 0.614(4) 0.479(5) 0.356(6) 0.378(7)	4.62(1) 4.33(2)	2.79 (1)	2.64(1) 2.16(2) 1.02(3) 1.04(4) 0.0533(5) 0.0476(6)	2.14 (1)
TDS	3210 (0)	2490(1) 2280(2) 2750(3) 2500(4) 2270(5) 2140(6) 2290(7)	3630(1) 3380(2)	1890 (1)	2870(1) 3040(2) 3360(3) 3140(4) 3460(5) 3360(6)	. (1)
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2) 100E-5(3) 100E-5(4) 100E-5(5) 100E-5(6) 100E-5(7)	100E-5(1) 100E-5(2)	0.0195 (1)	0.0413(1) 0.0607(2) 0.0456(3) 0.038(4) .00376(5) 100E-5(6)	100E-5 (1)
TOC	1.1 (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	2.55 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1) 0.15(2) 0.15(3) .(4) .(5) .(6) .(7)	0.15(1) 0.15(2)	0.15 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	0.15 (1)
VANADIUM	0.005 (0)	0.005(1) 0.005(2) 0.005(3) 0.005(4) 0.005(5) 0.005(6) 0.005(7)	0.005(1) 0.005(2)	0.0443 (1)	0.0778(1) 0.151(2) 0.117(3) 0.0882(4) 0.005(5) 0.005(6)	0.005 (1)
ZINC	0.171 (0)	0.0898(1) 0.232(2) 0.113(3) 0.0129(4) 0.0109(5) 0.0218(6) 100E-5(7)	0.206(1) 0.112(2)	0.0766 (1)	.00835(1) 0.0219(2) 0.0186(3) 0.0128(4) 100E-5(5) 100E-5(6)	0.112 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1) 0.464(2) 0.855(3) 0.957(4) 1.23(5) 1.38(6) 2.23(7)	0.493(1) 0.369(2)	0.349 (1)	0.784(3) 0.222(4) 0.383(5) 0.309(6)	0.341 (1)
ARSENIC	0.04 (0)	0.04(1) 0.04(2) 0.04(3) 0.04(4) 0.04(5) 0.04(6) 0.04(7)	0.04(1) 0.04(2)	0.04 (1)	0.555(3) 0.529(4) 0.463(5) 0.525(6)	0.04 (1)
BARIUM	0.171 (0)	0.114(1) 0.113(2) 0.0824(3) 0.073(4) 0.0482(5) 0.0493(6) 0.0474(7)	0.321(1) 0.281(2)	0.083 (1)	0.052(3) 0.0759(4) 0.0725(5) 0.0829(6)	0.045 (1)
BORON	13.3 (0)	8.54(1) 17.3(2) 6.46(3) 2.97(4) 2.03(5) 1.57(6) 1.54(7)	22.6(1) 27.5(2)	3.97 (1)	0.578(3) 0.002(4) 0.002(5) 0.002(6)	0.002 (1)
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.0025 (1)	0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6)	0.0025 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1270(1)	1790(1)	1780 (1)		1460 (1)
		1630(2)	1660(2)			
		894(3)			39(3)	
		629(4)			18.3(4)	
		559(5)			8.91(5)	
		512(6)			9.45(6)	
		593(7)				
CHROMIUM	0.0622 (0)	0.127(1)	0.2(1)	0.0256 (1)		0.061 (1)
		0.058(2)	0.318(2)			
		0.0025(3)			0.0025(3)	
		0.0025(4)			0.0128(4)	
		0.0025(5)			0.0233(5)	
		0.0025(6)			0.011(6)	
		0.0025(7)				
CL	4.46 (0)	1.27(1)	15(1)	. (1)		. (1)
		1.95(2)	22.5(2)			
		0.5(3)			.(3)	
		0.5(4)			.(4)	
		.(5)			.(5)	
		2.5(6)			.(6)	
		.(7)				
COBALT	0.075 (0)	0.075(1)	0.075(1)	0.075 (1)		0.075 (1)
		0.075(2)	0.075(2)			
		0.075(3)			0.075(3)	
		0.075(4)			0.075(4)	
		0.075(5)			0.075(5)	
		0.075(6)			0.075(6)	
		0.075(7)				
COND	9530 (0)	6000(1)	9000(1)	. (1)		. (1)
		4600(2)	9500(2)			
		4150(3)			.(3)	
		3350(4)			.(4)	
		2570(5)			.(5)	
		2700(6)			.(6)	
		2110(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0412(1) 0.0025(2)	0.0025 (1)	0.0108(3) 0.0131(4) 0.0129(5) 0.0198(6)	0.0025 (1)
F	0.785 (0)	2.32(1) 1.24(2) 0.44(3) 0.49(4) .(5) 0.405(6) .(7)	2.22(1) 0.775(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)
IRON	0.224 (0)	0.267(1) 0.181(2) 0.115(3) 0.052(4) 0.0925(5) 0.0714(6) 0.125(7)	0.198(1) 0.154(2)	0.209 (1)	0.002(3) 0.128(4) 0.0236(5) 0.0656(6)	0.127 (1)
LEAD	0.035 (0)	0.035(1) 0.035(2) 0.035(3) 0.035(4) 0.035(5) 0.035(6) 0.035(7)	0.035(1) 0.035(2)	0.035 (1)	0.0636(3) 0.181(4) 0.035(5) 0.035(6)	0.035 (1)
LITHIUM	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1) 0.698(2) 0.008(3) 0.106(4) 0.305(5) 0.226(6) 0.319(7)	1.08(1) 0.425(2)	0.235 (1)	0.36(3) 1.09(4) 0.865(5) 0.835(6)	0.092 (1)
MANGANESE	.00103 (0)	500E-6(1) 500E-6(2) 500E-6(3) 500E-6(4) 500E-6(5) 500E-6(6) 500E-6(7)	500E-6(1) 500E-6(2)	500E-6 (1)	.00357(3) .00141(4) 500E-6(5) .00195(6)	500E-6 (1)
MERCURY	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)
NICKEL	0.0143 (0)	0.01(1) 0.01(2) 0.0592(3) 0.01(4) 0.066(5) 0.01(6) 0.01(7)	0.01(1) 0.01(2)	0.01 (1)	0.01(3) 0.0697(4) 0.01(5) 0.01(6)	0.01 (1)
PH	11.8 (0)	12.2(1) 11.9(2) 11.8(3) 11.5(4) 11.3(5) 11.2(6) 11(7)	12.3(1) 12.2(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1)	20(1)	20 (1)		20 (1)
		20(2)	20(2)			
		20(3)			20(3)	
		20(4)			20(4)	
		20(5)			20(5)	
		20(6)			20(6)	
		20(7)				
SELENIUM	0.06 (0)	0.06(1)	0.06(1)	0.06 (1)		0.06 (1)
		0.06(2)	0.06(2)			
		0.06(3)			0.06(3)	
		0.06(4)			0.06(4)	
		0.06(5)			0.06(5)	
		0.06(6)			0.06(6)	
		0.06(7)				
SILICON	0.669 (0)	0.772(1)	0.519(1)	1.23 (1)		1.33 (1)
		0.746(2)	0.422(2)			
		1.45(3)			1.05(3)	
		1.04(4)			1.37(4)	
		1.67(5)			1.26(5)	
		2.33(6)			1.14(6)	
		3.38(7)				
SILVER	0.0025 (0)	0.0025(1)	0.0025(1)	0.0025 (1)		0.0025 (1)
		0.0025(2)	0.0025(2)			
		0.0025(3)			0.0125(3)	
		0.0025(4)			0.0176(4)	
		0.0025(5)			0.0123(5)	
		0.0025(6)			0.0349(6)	
		0.0025(7)				
SODIUM	16.7 (0)	36.3(1)	44.7(1)	40.3 (1)		57.2 (1)
		47.4(2)	71.1(2)			
		25.6(3)			2.5(3)	
		2.5(4)			11.3(4)	
		2.5(5)			16.4(5)	
		2.5(6)			6.46(6)	
		2.5(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1) 1360(2) 1360(3) 1440(4) 1240(5) 1290(6) 1080(7)	1240(1) 1310(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)
STRONTIUM	2.93 (0)	1.98(1) 1.69(2) 1(3) 0.614(4) 0.479(5) 0.356(6) 0.378(7)	4.62(1) 4.33(2)	5.64 (1)	0.158(3) 0.108(4) 0.0825(5) 0.0873(6)	6.06 (1)
TDS	3210 (0)	2490(1) 2280(2) 2750(3) 2500(4) 2270(5) 2140(6) 2290(7)	3630(1) 3380(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2) 100E-5(3) 100E-5(4) 100E-5(5) 100E-5(6) 100E-5(7)	100E-5(1) 100E-5(2)	100E-5 (1)	.00975(3) 0.0119(4) 100E-5(5) .00276(6)	100E-5 (1)
TOC	1.1 (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	. (1)	.(3) .(4) .(5) .(6)	. (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1) 0.15(2) 0.15(3) .(4) .(5) .(6) .(7)	0.15(1) 0.15(2)	0.15 (1)	.(3) .(4) .(5) .(6)	0.15 (1)
VANADIUM	0.005 (0)	0.005(1) 0.005(2) 0.005(3) 0.005(4) 0.005(5) 0.005(6) 0.005(7)	0.005(1) 0.005(2)	0.005 (1)	0.005(3) 0.005(4) 0.005(5) 0.005(6)	0.005 (1)
ZINC	0.171 (0)	0.0898(1) 0.232(2) 0.113(3) 0.0129(4) 0.0109(5) 0.0218(6) 100E-5(7)	0.206(1) 0.112(2)	0.212 (1)	.00861(3) 100E-5(4) 100E-5(5) 100E-5(6)	0.24 (1)

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1) 0.464(2) 0.855(3) 0.957(4) 1.23(5) 1.38(6) 2.23(7)	0.493(1) 0.369(2)	0.857 (1)	0.481(1) 0.527(2) 1.31(3) 0.627(4) .(5) .(6)	
ARSENIC	0.04 (0)	0.04(1) 0.04(2) 0.04(3) 0.04(4) 0.04(5) 0.04(6) 0.04(7)	0.04(1) 0.04(2)	. (1)	.(1) .(2) .(3) .(4) .(5) .(6)	
BARIUM	0.171 (0)	0.114(1) 0.113(2) 0.0824(3) 0.073(4) 0.0482(5) 0.0443(6) 0.0474(7)	0.321(1) 0.281(2)	0.157 (1)	0.245(1) 0.256(2) 0.144(3) 0.228(4) .(5) .(6)	
BORON	13.3 (0)	8.54(1) 17.3(2) 6.46(3) 2.97(4) 2.03(5) 1.57(6) 1.54(7)	22.6(1) 27.5(2)	0.768 (1)	1.43(1) 2.21(2) 1.97(3) 2.8(4) .(5) .(6)	
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.0025 (1)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) .(5) .(6)	

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1970(1)	1790(1)	560 (1)	667(1)	
		1630(2)	1660(2)		821(2)	
		894(3)			823(3)	
		629(4)			957(4)	
		559(5)			.(5)	
		512(6)			.(6)	
		593(7)				
CHROMIUM	0.0622 (0)	0.127(1)	0.2(1)	0.0838 (1)	0.0555(1)	
		0.058(2)	0.318(2)		0.0679(2)	
		0.0025(3)			0.131(3)	
		0.0025(4)			0.0729(4)	
		0.0025(5)			.(5)	
		0.0025(6)			.(6)	
		0.0025(7)				
CL	4.46 (0)	1.27(1)	15(1)	. (1)	.(1)	
		1.95(2)	22.5(2)		.(2)	
		0.5(3)			.(3)	
		0.5(4)			.(4)	
		.(5)			.(5)	
		2.5(6)			.(6)	
		.(7)				
COBALT	0.075 (0)	0.075(1)	0.075(1)	1.27 (1)	0.527(1)	
		0.075(2)	0.075(2)		0.705(2)	
		0.075(3)			2.25(3)	
		0.075(4)			0.851(4)	
		0.075(5)			.(5)	
		0.075(6)			.(6)	
		0.075(7)				
COND	9530 (0)	6000(1)	9000(1)	1580 (1)	2570(1)	
		4600(2)	9500(2)		3880(2)	
		4150(3)			4380(3)	
		3350(4)			4700(4)	
		2570(5)			5140(5)	
		2700(6)			5700(6)	
		2110(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0412(1) 0.0025(2)	0.107 (1)	0.0601(1) 0.0662(2) 0.15(3) 0.0699(4) .(5) .(6)	
F	0.785 (0)	2.32(1) 1.24(2) 0.44(3) 0.49(4) .(5) 0.405(6) .(7)	2.22(1) 0.775(2)	0.625 (1)	0.375(1) 0.43(2) 0.4(3) 0.34(4) 0.575(5) 0.5(6)	
IRON	0.224 (0)	0.267(1) 0.181(2) 0.115(3) 0.052(4) 0.0925(5) 0.0714(6) 0.125(7)	0.198(1) 0.154(2)	0.0592 (1)	0.0693(1) 0.0409(2) 0.126(3) 0.109(4) .(5) .(6)	
LEAD	0.035 (0)	0.035(1) 0.035(2) 0.035(3) 0.035(4) 0.035(5) 0.035(6) 0.035(7)	0.035(1) 0.035(2)	. (1)	.(1) .(2) .(3) .(4) .(5) .(6)	
LITHIUM	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	0.005 (1)	0.005(1) 0.0125(2) 0.03(3) 0.0175(4) .(5) .(6)	

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1)	1.08(1)	.00352 (1)	.00581(1)	
		0.698(2)	0.425(2)		.00359(2)	
		0.888(3)			.00593(3)	
		0.106(4)			.00542(4)	
		0.305(5)			.(5)	
		0.226(6)			.(6)	
		0.319(7)				
MANGANESE	.00103 (0)	500E-6(1)	500E-6(1)	0.0111 (1)	.00564(1)	
		500E-6(2)	500E-6(2)		.00708(2)	
		500E-6(3)			0.0187(3)	
		500E-6(4)			.00882(4)	
		500E-6(5)			.(5)	
		500E-6(6)			.(6)	
		500E-6(7)				
MERCURY	. (0)	.(1)	.(1)	500E-6 (1)	500E-6(1)	
		.(2)	.(2)		500E-6(2)	
		.(3)			500E-6(3)	
		.(4)			500E-6(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				
NICKEL	0.0143 (0)	0.01(1)	0.01(1)	0.186 (1)	0.124(1)	
		0.01(2)	0.01(2)		0.152(2)	
		0.0592(3)			0.291(3)	
		0.01(4)			0.156(4)	
		0.066(5)			.(5)	
		0.01(6)			.(6)	
		0.01(7)				
PH	11.8 (0)	12.2(1)	12.3(1)	9.31 (1)	11.7(1)	
		11.9(2)	12.2(2)		12(2)	
		11.8(3)			12(3)	
		11.5(4)			12.1(4)	
		11.3(5)			12.1(5)	
		11.2(6)			12.3(6)	
		11(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1) 20(2) 20(3) 20(4) 20(5) 20(6) 20(7)	20(1) 20(2)	429 (1)	272(1) 345(2) 723(3) 397(4) .(5) .(6)	
SELENIUM	0.06 (0)	0.06(1) 0.06(2) 0.06(3) 0.06(4) 0.06(5) 0.06(6) 0.06(7)	0.06(1) 0.06(2)	0.0025 (1)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) .(5) .(6)	
SILICON	0.669 (0)	0.772(1) 0.746(2) 1.45(3) 1.04(4) 1.67(5) 2.33(6) 3.38(7)	0.519(1) 0.422(2)	2.5 (1)	0.85(1) 0.531(2) 0.699(3) 0.47(4) .(5) .(6)	
SILVER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.078 (1)	0.0304(1) 0.0393(2) 0.139(3) 0.048(4) .(5) .(6)	
SODIUM	16.7 (0)	36.3(1) 47.4(2) 25.6(3) 2.5(4) 2.5(5) 2.5(6) 2.5(7)	44.7(1) 71.1(2)	2.5 (1)	2.5(1) 2.5(2) 4.27(3) 2.5(4) .(5) .(6)	

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* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1)	1240(1)	940 (1)	800(1)	
		1360(2)	1310(2)		980(2)	
		1360(3)			1040(3)	
		1440(4)			1070(4)	
		1240(5)			1080(5)	
		1290(6)			1190(6)	
		1080(7)				
STRONTIUM	2.93 (0)	1.98(1)	4.62(1)	1.09 (1)	2.19(1)	
		1.69(2)	4.33(2)		2.59(2)	
		1(3)			2.13(3)	
		0.614(4)			2.59(4)	
		0.479(5)			.(5)	
		0.356(6)			.(6)	
		0.378(7)				
TDS	3210 (0)	2490(1)	3630(1)	1660 (1)	1950(1)	
		2280(2)	3380(2)		2590(2)	
		2750(3)			2570(3)	
		2500(4)			2880(4)	
		2270(5)			3290(5)	
		2140(6)			3160(6)	
		2290(7)				
TITANIUM	100E-5 (0)	100E-5(1)	100E-5(1)	0.04 (1)	0.0242(1)	
		100E-5(2)	100E-5(2)		0.033(2)	
		100E-5(3)			0.0656(3)	
		100E-5(4)			0.0378(4)	
		100E-5(5)			.(5)	
		100E-5(6)			.(6)	
		100E-5(7)				
TOC	1.1 (0)	.(1)	.(1)	. (1)	.(1)	
		.(2)	.(2)		.(2)	
		.(3)			.(3)	
		.(4)			.(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1)	0.15(1)	. (1)	.(1)	
		0.15(2)	0.15(2)		.(2)	
		0.15(3)			.(3)	
		.(4)			.(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				
VANADIUM	0.005 (0)	0.005(1)	0.005(1)	0.102 (1)	0.0414(1)	
		0.005(2)	0.005(2)		0.0558(2)	
		0.005(3)			0.172(3)	
		0.005(4)			0.0649(4)	
		0.005(5)			.(5)	
		0.005(6)			.(6)	
		0.005(7)				
ZINC	0.171 (0)	0.0898(1)	0.206(1)	0.0136 (1)	100E-5(1)	
		0.232(2)	0.112(2)		.00875(2)	
		0.113(3)			0.0231(3)	
		0.0129(4)			.00536(4)	
		0.0109(5)			.(5)	
		0.0218(6)			.(6)	
		100E-5(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1) 0.464(2) 0.855(3) 0.957(4) 1.23(5) 1.38(6) 2.23(7)	0.493(1) 0.369(2)	1.02 (1)	0.943(1) 4.94(2) 3.1(3) 0.995(4) .(5) .(6)	
ARSENIC	0.04 (0)	0.04(1) 0.04(2) 0.04(3) 0.04(4) 0.04(5) 0.04(6) 0.04(7)	0.04(1) 0.04(2)	. (1)	.(1) .(2) .(3) .(4) .(5) .(6)	
BARIUM	0.171 (0)	0.114(1) 0.113(2) 0.0824(3) 0.073(4) 0.0482(5) 0.0443(6) 0.0474(7)	0.321(1) 0.281(2)	0.233 (1)	0.229(1) 0.126(2) 0.142(3) 0.162(4) .(5) .(6)	
BORON	13.3 (0)	8.54(1) 17.3(2) 6.46(3) 2.97(4) 2.03(5) 1.57(6) 1.54(7)	22.6(1) 27.5(2)	0.431 (1)	1.37(1) 0.949(2) 1.38(3) 2.27(4) .(5) .(6)	
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0025(1) 0.0025(2)	0.0025 (1)	0.0025(1) 0.165(2) 0.0448(3) 0.0025(4) .(5) .(6)	

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1270(1) 1630(2) 894(3) 629(4) 559(5) 512(6) 593(7)	1790(1) 1660(2)	545 (1)	858(1) 438(2) 718(3) 1090(4) .(5) .(6)	
CHROMIUM	0.0622 (0)	0.127(1) 0.058(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.2(1) 0.318(2)	0.102 (1)	0.101(1) 0.376(2) 0.254(3) 0.0949(4) .(5) .(6)	
CL	4.46 (0)	1.27(1) 1.95(2) 0.5(3) 0.5(4) .(5) 2.5(6) .(7)	15(1) 22.5(2)	. (1)	.(1) .(2) .(3) .(4) .(5) .(6)	
COBALT	0.075 (0)	0.075(1) 0.075(2) 0.075(3) 0.075(4) 0.075(5) 0.075(6) 0.075(7)	0.075(1) 0.075(2)	1.53 (1)	1.52(1) 8.52(2) 5.4(3) 1.32(4) .(5) .(6)	
COND	9530 (0)	6000(1) 4600(2) 4150(3) 3350(4) 2570(5) 2700(6) 2110(7)	9000(1) 9500(2)	1530 (1)	5100(1) 6500(2) 6900(3) 6700(4) 7350(5) 7130(6)	

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP				
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1) 0.0025(2) 0.0025(3) 0.0025(4) 0.0025(5) 0.0025(6) 0.0025(7)	0.0412(1) 0.0025(2)	0.103 (1)	0.0943(1) 0.494(2) 0.313(3) 0.0747(4) .(5) .(6)	
F	0.785 (0)	2.32(1) 1.24(2) 0.44(3) 0.49(4) .(5) 0.405(6) .(7)	2.22(1) 0.775(2)	0.265 (1)	0.34(1) 0.4(2) 0.39(3) 0.345(4) 0.37(5) .(6)	
IRON	0.224 (0)	0.267(1) 0.181(2) 0.115(3) 0.052(4) 0.0925(5) 0.0714(6) 0.125(7)	0.198(1) 0.154(2)	0.177 (1)	0.136(1) 0.355(2) 0.237(3) 0.41(4) .(5) .(6)	
LEAD	0.035 (0)	0.035(1) 0.035(2) 0.035(3) 0.035(4) 0.035(5) 0.035(6) 0.035(7)	0.035(1) 0.035(2)	. (1)	.(1) .(2) .(3) .(4) .(5) .(6)	
LITHIUM	. (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	0.0175 (1)	0.0325(1) 0.055(2) 0.045(3) 0.06(4) .(5) .(6)	

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1)	1.08(1)	0.0025 (1)	.00221(1)	
		0.698(2)	0.425(2)		.00253(2)	
		0.808(3)			.00174(3)	
		0.106(4)			.00355(4)	
		0.305(5)			.(5)	
		0.226(6)			.(6)	
		0.319(7)				
MANGANESE	.00103 (0)	500E-6(1)	500E-6(1)	0.0182 (1)	0.0173(1)	
		500E-6(2)	500E-6(2)		0.0636(2)	
		500E-6(3)			0.0417(3)	
		500E-6(4)			0.0277(4)	
		500E-6(5)			.(5)	
		500E-6(6)			.(6)	
		500E-6(7)				
MERCURY	. (0)	.(1)	.(1)	500E-6 (1)	500E-6(1)	
		.(2)	.(2)		500E-6(2)	
		.(3)			500E-6(3)	
		.(4)			500E-6(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				
NICKEL	0.0143 (0)	0.01(1)	0.01(1)	0.186 (1)	0.189(1)	
		0.01(2)	0.01(2)		0.74(2)	
		0.0592(3)			0.498(3)	
		0.01(4)			0.175(4)	
		0.066(5)			.(5)	
		0.01(6)			.(6)	
		0.01(7)				
PH	11.8 (0)	12.2(1)	12.3(1)	11.1 (1)	12.1(1)	
		11.9(2)	12.2(2)		12.2(2)	
		11.8(3)			12.2(3)	
		11.5(4)			12.2(4)	
		11.3(5)			12.2(5)	
		11.2(6)			12.4(6)	
		11(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1)	20(1)	494 (1)	551(1)	
		20(2)	20(2)		2210(2)	
		20(3)			1490(3)	
		20(4)			545(4)	
		20(5)			.(5)	
		20(6)			.(6)	
		20(7)				
SELENIUM	0.06 (0)	0.06(1)	0.06(1)	0.0025 (1)	0.0025(1)	
		0.06(2)	0.06(2)		0.0025(2)	
		0.06(3)			0.0025(3)	
		0.06(4)			0.0025(4)	
		0.06(5)			.(5)	
		0.06(6)			.(6)	
		0.06(7)				
SILICON	0.669 (0)	0.772(1)	0.519(1)	1.17 (1)	0.588(1)	
		0.746(2)	0.422(2)		1.98(2)	
		1.45(3)			1.28(3)	
		1.04(4)			0.619(4)	
		1.67(5)			.(5)	
		2.33(6)			.(6)	
		3.38(7)				
SILVER	0.0025 (0)	0.0025(1)	0.0025(1)	0.0914 (1)	0.0905(1)	
		0.0025(2)	0.0025(2)		0.514(2)	
		0.0025(3)			0.33(3)	
		0.0025(4)			0.0817(4)	
		0.0025(5)			.(5)	
		0.0025(6)			.(6)	
		0.0025(7)				
SODIUM	16.7 (0)	36.3(1)	44.7(1)	2.5 (1)	2.5(1)	
		47.4(2)	71.1(2)		14.8(2)	
		25.6(3)			9.34(3)	
		2.5(4)			2.5(4)	
		2.5(5)			.(5)	
		2.5(6)			.(6)	
		2.5(7)				

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFRC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1) 1360(2) 1360(3) 1440(4) 1240(5) 1290(6) 1080(7)	1240(1) 1310(2)	740 (1)	965(1) 1090(2) 1140(3) 1080(4) 1120(5) 1090(6)	
STRONTIUM	2.93 (0)	1.98(1) 1,69(2) 1(3) 0.614(4) 0.479(5) 0.356(6) 0,378(7)	4,62(1) 4,33(2)	1.58 (1)	2.24(1) 0,751(2) 1.26(3) 2.4(4) .(5) .(6)	
TDS	3210 (0)	2490(1) 2280(2) 2750(3) 2500(4) 2270(5) 2140(6) 2290(7)	3630(1) 3380(2)	1060 (1)	2500(1) 3240(2) 3380(3) 3110(4) 3550(5) 3540(6)	
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2) 100E-5(3) 100E-5(4) 100E-5(5) 100E-5(6) 100E-5(7)	100E-5(1) 100E-5(2)	0,0458 (1)	0.05(1) 0,186(2) 0.13(3) 0.0546(4) .(5) .(6)	
TOC	1.1 (0)	.(1) .(2) .(3) .(4) .(5) .(6) .(7)	.(1) .(2)	3.8 (1)	.(1) .(2) .(3) .(4) .(5) .(6)	

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1)	0.15(1)	. (1)	.(1)	
		0.15(2)	0.15(2)		.(2)	
		0.15(3)			.(3)	
		.(4)			.(4)	
		.(5)			.(5)	
		.(6)			.(6)	
		.(7)				
VANADIUM	0.005 (0)	0.005(1)	0.005(1)	0.114 (1)	0.115(1)	
		0.005(2)	0.005(2)		0.638(2)	
		0.005(3)			0.408(3)	
		0.005(4)			0.102(4)	
		0.005(5)			.(5)	
		0.005(6)			.(6)	
		0.005(7)				
ZINC	0.171 (0)	0.0898(1)	0.206(1)	0.0154 (1)	0.0186(1)	
		0.232(2)	0.112(2)		0.0956(2)	
		0.113(3)			0.0631(3)	
		0.0129(4)			0.0156(4)	
		0.0109(5)			.(5)	
		0.0218(6)			.(6)	
		100E-5(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.614 (0)	0.662(1)	0.493(1)	1.73 (1)	2.81(1)	2.57 (1)
		0.464(2)	0.369(2)		1.37(2)	. (2)
		0.855(3)			4.52(3)	. (3)
		0.957(4)			1.41(4)	. (4)
		1.23(5)			.(5)	. (5)
		1.38(6)			.(6)	
		2.23(7)				
ARSENIC	0.04 (0)	0.04(1)	0.04(1)	. (1)	.(1)	. (1)
		0.04(2)	0.04(2)		.(2)	. (2)
		0.04(3)			.(3)	. (3)
		0.04(4)			.(4)	. (4)
		0.04(5)			.(5)	. (5)
		0.04(6)			.(6)	
		0.04(7)				
BARIUM	0.171 (0)	0.114(1)	0.321(1)	0.19 (1)	0.127(1)	0.173 (1)
		0.113(2)	0.281(2)		0.174(2)	. (2)
		0.0824(3)			0.0963(3)	. (3)
		0.073(4)			0.12(4)	. (4)
		0.0482(5)			.(5)	. (5)
		0.0443(6)			.(6)	
		0.0474(7)				
BORON	13.3 (0)	8.54(1)	22.6(1)	0.639 (1)	1.97(1)	0.41 (1)
		17.3(2)	27.5(2)		4.01(2)	. (2)
		6.46(3)			1.56(3)	. (3)
		2.97(4)			3.76(4)	. (4)
		2.03(5)			.(5)	. (5)
		1.57(6)			.(6)	
		1.54(7)				
CADMIUM	0.0025 (0)	0.0025(1)	0.0025(1)	0.024 (1)	0.056(1)	0.0925 (1)
		0.0025(2)	0.0025(2)		0.0025(2)	. (2)
		0.0025(3)			0.143(3)	. (3)
		0.0025(4)			0.0025(4)	. (4)
		0.0025(5)			.(5)	. (5)
		0.0025(6)			.(6)	
		0.0025(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PERC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
CALCIUM	1700 (0)	1270(1)	1790(1)	549 (1)	858(1)	200 (1)
		1630(2)	1660(2)		1250(2)	. (2)
		894(3)			511(3)	. (3)
		629(4)			1090(4)	. (4)
		559(5)			.(5)	. (5)
		512(6)			.(6)	
		593(7)				
CHROMIUM	0.0622 (0)	0.127(1)	0.2(1)	0.124 (1)	0.218(1)	0.182 (1)
		0.058(2)	0.318(2)		0.119(2)	. (2)
		0.0025(3)			0.351(3)	. (3)
		0.0025(4)			0.135(4)	. (4)
		0.0025(5)			.(5)	. (5)
		0.0025(6)			.(6)	
		0.0025(7)				
CL	4.46 (0)	1.27(1)	15(1)	. (1)	.(1)	. (1)
		1.95(2)	22.5(2)		.(2)	. (2)
		0.5(3)			.(3)	. (3)
		0.5(4)			.(4)	. (4)
		.(5)			.(5)	. (5)
		2.5(6)			.(6)	
		.(7)				
COBALT	0.075 (0)	0.075(1)	0.075(1)	2.84 (1)	4.86(1)	4.29 (1)
		0.075(2)	0.075(2)		2.22(2)	. (2)
		0.075(3)			7.96(3)	. (3)
		0.075(4)			2.41(4)	. (4)
		0.075(5)			.(5)	. (5)
		0.075(6)			.(6)	
		0.075(7)				
COND	9530 (0)	6000(1)	9000(1)	2630 (1)	6400(1)	1540 (1)
		4600(2)	9500(2)		7230(2)	1470 (2)
		4150(3)			7280(3)	1650 (3)
		3350(4)			6900(4)	1510 (4)
		2570(5)			7650(5)	1490 (5)
		2700(6)			7800(6)	
		2110(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
COPPER	0.0025 (0)	0.0025(1)	0.0412(1)	0.165 (1)	0.282(1)	0.248 (1)
		0.0025(2)	0.0025(2)		0.127(2)	. (2)
		0.0025(3)			0.458(3)	. (3)
		0.0025(4)			0.137(4)	. (4)
		0.0025(5)			.(5)	. (5)
		0.0025(6)			.(6)	
		0.0025(7)				
F	0.785 (0)	2.32(1)	2.22(1)	0.635 (1)	0.8(1)	. (1)
		1.24(2)	0.775(2)		0.88(2)	. (2)
		0.44(3)			0.58(3)	. (3)
		0.49(4)			0.53(4)	. (4)
		.(5)			0.71(5)	. (5)
		0.405(6)			0.585(6)	
		.(7)				
IRON	0.224 (0)	0.267(1)	0.198(1)	0.0987 (1)	0.173(1)	0.137 (1)
		0.181(2)	0.154(2)		0.0736(2)	. (2)
		0.115(3)			0.261(3)	. (3)
		0.052(4)			0.0918(4)	. (4)
		0.0925(5)			.(5)	. (5)
		0.0714(6)			.(6)	
		0.125(7)				
LEAD	0.035 (0)	0.035(1)	0.035(1)	. (1)	.(1)	. (1)
		0.035(2)	0.035(2)		.(2)	. (2)
		0.035(3)			.(3)	. (3)
		0.035(4)			.(4)	. (4)
		0.035(5)			.(5)	. (5)
		0.035(6)			.(6)	
		0.035(7)				
LITHIUM	. (0)	.(1)	.(1)	0.0275 (1)	0.075(1)	0.08 (1)
		.(2)	.(2)		0.04(2)	. (2)
		.(3)			0.085(3)	. (3)
		.(4)			0.065(4)	. (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
MAGNESIUM	1.91 (0)	3.03(1)	1.08(1)	.00856 (1)	0.0067(1)	0.0138 (1)
		0.698(2)	0.425(2)		.00641(2)	. (2)
		0.888(3)			.00389(3)	. (3)
		0.106(4)			0.0082(4)	. (4)
		0.305(5)			.(5)	. (5)
		0.226(6)			.(6)	
		0.319(7)				
MANGANESE	.00103 (0)	500E-6(1)	500E-6(1)	0.0215 (1)	0.0362(1)	0.0323 (1)
		500E-6(2)	500E-6(2)		0.0181(2)	. (2)
		500E-6(3)			0.0562(3)	. (3)
		500E-6(4)			0.0195(4)	. (4)
		500E-6(5)			.(5)	. (5)
		500E-6(6)			.(6)	
		500E-6(7)				
MERCURY	. (0)	.(1)	.(1)	500E-6 (1)	500E-6(1)	500E-6 (1)
		.(2)	.(2)		500E-6(2)	. (2)
		.(3)			500E-6(3)	. (3)
		.(4)			500E-6(4)	. (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				
NICKEL	0.0143 (0)	0.01(1)	0.01(1)	0.275 (1)	0.461(1)	0.358 (1)
		0.01(2)	0.01(2)		0.268(2)	. (2)
		0.0592(3)			0.668(3)	. (3)
		0.01(4)			0.258(4)	. (4)
		0.066(5)			.(5)	. (5)
		0.01(6)			.(6)	
		0.01(7)				
PH	11.8 (0)	12.2(1)	12.3(1)	11.9 (1)	12.1(1)	11.1 (1)
		11.9(2)	12.2(2)		12.2(2)	9.19 (2)
		11.8(3)			12.2(3)	8.4 (3)
		11.5(4)			12.3(4)	8.46 (4)
		11.3(5)			12.2(5)	8.25 (5)
		11.2(6)			12.4(6)	
		11(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
POTASSIUM	20 (0)	20(1)	20(1)	848 (1)	1370(1)	1150 (1)
		20(2)	20(2)		771(2)	. (2)
		20(3)			2080(3)	. (3)
		20(4)			811(4)	. (4)
		20(5)			.(5)	. (5)
		20(6)			.(6)	
		20(7)				
SELENIUM	0.06 (0)	0.06(1)	0.06(1)	0.0025 (1)	0.0025(1)	0.0025 (1)
		0.06(2)	0.06(2)		0.0025(2)	. (2)
		0.06(3)			0.0025(3)	. (3)
		0.06(4)			0.0025(4)	. (4)
		0.06(5)			.(5)	. (5)
		0.06(6)			.(6)	
		0.06(7)				
SILICON	0.669 (0)	0.772(1)	0.519(1)	1.13 (1)	1.19(1)	5.09 (1)
		0.746(2)	0.422(2)		0.631(2)	. (2)
		1.45(3)			1.76(3)	. (3)
		1.04(4)			0.614(4)	. (4)
		1.67(5)			.(5)	. (5)
		2.33(6)			.(6)	
		3.38(7)				
SILVER	0.0025 (0)	0.0025(1)	0.0025(1)	0.175 (1)	0.294(1)	0.258 (1)
		0.0025(2)	0.0025(2)		0.134(2)	. (2)
		0.0025(3)			0.483(3)	. (3)
		0.0025(4)			0.15(4)	. (4)
		0.0025(5)			.(5)	. (5)
		0.0025(6)			.(6)	
		0.0025(7)				
SODIUM	16.7 (0)	36.3(1)	44.7(1)	6.62 (1)	9.06(1)	8.51 (1)
		47.4(2)	71.1(2)		2.5(2)	. (2)
		25.6(3)			13.6(3)	. (3)
		2.5(4)			4.02(4)	. (4)
		2.5(5)			.(5)	. (5)
		2.5(6)			.(6)	
		2.5(7)				

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(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
SO4	1230 (0)	1290(1)	1240(1)	720 (1)	1230(1)	520 (1)
		1360(2)	1310(2)		1150(2)	547 (2)
		1360(3)			1180(3)	574 (3)
		1440(4)			1160(4)	660 (4)
		1240(5)			1280(5)	484 (5)
		1290(6)			1350(6)	
		1080(7)				
STRONTIUM	2.93 (0)	1.98(1)	4.62(1)	2.83 (1)	1.79(1)	2.57 (1)
		1.69(2)	4.33(2)		2.35(2)	. (2)
		1(3)			0.775(3)	. (3)
		0.614(4)			2(4)	. (4)
		0.479(5)			.(5)	. (5)
		0.356(6)			.(6)	
		0.378(7)				
TDS	3210 (0)	2490(1)	3630(1)	1670 (1)	2760(1)	1120 (1)
		2280(2)	3380(2)		3860(2)	1260 (2)
		2750(3)			3790(3)	1410 (3)
		2500(4)			3660(4)	1350 (4)
		2270(5)			4080(5)	1320 (5)
		2140(6)			3920(6)	
		2290(7)				
TITANIUM	100E-5 (0)	100E-5(1)	100E-5(1)	0.0716 (1)	0.119(1)	0.0925 (1)
		100E-5(2)	100E-5(2)		0.0726(2)	. (2)
		100E-5(3)			0.176(3)	. (3)
		100E-5(4)			0.0723(4)	. (4)
		100E-5(5)			.(5)	. (5)
		100E-5(6)			.(6)	
		100E-5(7)				
TOC	1.1 (0)	.(1)	.(1)	2.65 (1)	.(1)	. (1)
		.(2)	.(2)		.(2)	. (2)
		.(3)			.(3)	. (3)
		.(4)			.(4)	. (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				

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TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 7 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
URANIUM	0.15 (0)	0.15(1)	0.15(1)	. (1)	.(1)	. (1)
		0.15(2)	0.15(2)		.(2)	. (2)
		0.15(3)			.(3)	. (3)
		.(4)			.(4)	. (4)
		.(5)			.(5)	. (5)
		.(6)			.(6)	
		.(7)				
VANADIUM	0.005 (0)	0.005(1)	0.005(1)	0.216 (1)	0.371(1)	0.32 (1)
		0.005(2)	0.005(2)		0.174(2)	. (2)
		0.005(3)			0.595(3)	. (3)
		0.005(4)			0.186(4)	. (4)
		0.005(5)			.(5)	. (5)
		0.005(6)			.(6)	
		0.005(7)				
ZINC	0.171 (0)	0.0898(1)	0.206(1)	0.0325 (1)	0.0555(1)	0.0516 (1)
		0.232(2)	0.112(2)		0.0281(2)	. (2)
		0.113(3)			0.0912(3)	. (3)
		0.0129(4)			0.0261(4)	. (4)
		0.0109(5)			.(5)	. (5)
		0.0218(6)			.(6)	
		100E-5(7)				

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFDC WASTE AND ATTENUATION BY SHALE LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
				• (1)		
ALUMINUM	0.768 (0)			• (1)		
ARSENIC	0.04 (0)			• (1)		
BARIUM	0.283 (0)			• (1)		
BORON	12.3 (0)			• (1)		
CADMIUM	0.0025 (0)			• (1)		
CALCIUM	1120 (0)			• (1)		
CHROMIUM	0.0025 (0)			• (1)		
CL	8.62 (0)			• (1)		
COBALT	0.075 (0)			• (1)		
COND	24700 (0)			4030 (1)		
COPPER	0.0025 (0)			• (1)		
F	0.968 (0)			0.2 (1)		
IRON	0.264 (0)			• (1)		
LEAD	0.035 (0)			• (1)		
LITHIUM	• (0)			• (1)		
MAGNESIUM	0.865 (0)			• (1)		
MANGANESE	500E-6 (0)			• (1)		
MERCURY	• (0)			• (1)		
NICKEL	0.01 (0)			• (1)		
PH	12.2 (0)			12 (1)		
POTASSIUM	20 (0)			• (1)		
SELENIUM	0.06 (0)			• (1)		
SILICON	0.65 (0)			• (1)		
SILVER	0.0025 (0)			• (1)		
SODIUM	3.73 (0)			• (1)		
SO4	1570 (0)			965 (1)		
STRONTIUM	1.82 (0)			• (1)		
TDS	3650 (0)			2200 (1)		
TITANIUM	100E-5 (0)			• (1)		
TOC	3.7 (0)			• (1)		
URANIUM	0.15 (0)			• (1)		
VANADIUM	0.005 (0)			• (1)		
ZINC	0.323 (0)			• (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.768 (0)			. (1)		
ARSENIC	0.04 (0)			. (1)		
BARIUM	0.283 (0)			. (1)		
BORON	12.3 (0)			. (1)		
CADMIUM	0.0025 (0)			. (1)		
CALCIUM	1120 (0)			. (1)		
CHROMIUM	0.0025 (0)			. (1)		
CL	8.62 (0)			. (1)		
COBALT	0.075 (0)			. (1)		
COND	24700 (0)			4530 (1)		
COPPER	0.0025 (0)			. (1)		
F	0.968 (0)			0.52 (1)		
IRON	0.264 (0)			. (1)		
LEAD	0.035 (0)			. (1)		
LITHIUM	. (0)			. (1)		
MAGNESIUM	0.865 (0)			. (1)		
MANGANESE	500E-6 (0)			. (1)		
MERCURY	. (0)			. (1)		
NICKEL	0.01 (0)			. (1)		
PH	12.2 (0)			12 (1)		
POTASSIUM	20 (0)			. (1)		
SELENIUM	0.06 (0)			. (1)		
SILICON	0.65 (0)			. (1)		
SILVER	0.0025 (0)			. (1)		
SODIUM	3.73 (0)			. (1)		
SO4	1570 (0)			1250 (1)		
STRONTIUM	1.82 (0)			. (1)		
TDS	3650 (0)			2630 (1)		
TITANIUM	100E-5 (0)			. (1)		
TOC	3.7 (0)			. (1)		
URANIUM	0.15 (0)			. (1)		
VANADIUM	0.005 (0)			. (1)		
ZINC	0.323 (0)			. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.768 (0)			. (1)		
ARSENIC	0.04 (0)			. (1)		
BARIUM	0.283 (0)			. (1)		
BORON	12.3 (0)			. (1)		
CADMIUM	0.0025 (0)			. (1)		
CALCIUM	1120 (0)			. (1)		
CHROMIUM	0.0025 (0)			. (1)		
CL	8.62 (0)			. (1)		
COBALT	0.075 (0)			. (1)		
COND	24700 (0)			5540 (1)		
COPPER	0.0025 (0)			. (1)		
F	0.968 (0)			0.73 (1)		
IRON	0.264 (0)			. (1)		
LEAD	0.035 (0)			. (1)		
LITHIUM	. (0)			. (1)		
MAGNESIUM	0.865 (0)			. (1)		
MANGANESE	500E-6 (0)			. (1)		
MERCURY	. (0)			. (1)		
NICKEL	0.01 (0)			. (1)		
PH	12.2 (0)			12.2 (1)		
POTASSIUM	20 (0)			. (1)		
SELENIUM	0.06 (0)			. (1)		
SILICON	0.65 (0)			. (1)		
SILVER	0.0025 (0)			. (1)		
SODIUM	3.73 (0)			. (1)		
SO4	1570 (0)			1190 (1)		
STRONTIUM	1.82 (0)			. (1)		
TDS	3650 (0)			2880 (1)		
TITANIUM	100E-5 (0)			. (1)		
TOC	3.7 (0)			. (1)		
URANIUM	0.15 (0)			. (1)		
VANADIUM	0.005 (0)			. (1)		
ZINC	0.323 (0)			. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

+ LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP											
	STEP 1		STEP 2		STEP 3		STEP 4		STEP 5		STEP 6	
ALUMINUM	0.768	(0)										
ARSENIC	0.04	(0)										
BARIUM	0.283	(0)										
BORON	12.3	(0)										
CADMIUM	0.0025	(0)										
CALCIUM	1120	(0)										
CHROMIUM	0.0025	(0)										
CL	8.62	(0)										
COBALT	0.075	(0)										
COND	24700	(0)										
COPPER	0.0025	(0)										
F	0.968	(0)										
IRON	0.264	(0)										
LEAD	0.035	(0)										
LITHIUM	.	(0)										
MAGNESIUM	0.865	(0)										
MANGANESE	500E-6	(0)										
MERCURY	.	(0)										
NICKEL	0.01	(0)										
PH	12.2	(0)										
POTASSIUM	20	(0)										
SELENIUM	0.06	(0)										
SILICON	0.65	(0)										
SILVER	0.0025	(0)										
SODIUM	3.73	(0)										
SO4	1570	(0)										
STRONTIUM	1.82	(0)										
TDS	3650	(0)										
TITANIUM	100E-5	(0)										
TOC	3.7	(0)										
URANIUM	0.15	(0)										
VANADIUM	0.005	(0)										
ZINC	0.323	(0)										

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.768 (0)			. (1)		
ARSENIC	0.04 (0)			. (1)		
BARIUM	0.283 (0)			. (1)		
BORON	12.3 (0)			. (1)		
CADMIUM	0.0025 (0)			. (1)		
CALCIUM	1120 (0)			. (1)		
CHROMIUM	0.0025 (0)			. (1)		
CL	8.62 (0)			. (1)		
COBALT	0.075 (0)			. (1)		
COND	24700 (0)			3680 (1)		
COPPER	0.0025 (0)			. (1)		
F	0.968 (0)			0.645 (1)		
IRON	0.264 (0)			. (1)		
LEAD	0.035 (0)			. (1)		
LITHIUM	. (0)			. (1)		
MAGNESIUM	0.865 (0)			. (1)		
MANGANESE	500E-6 (0)			. (1)		
MERCURY	. (0)			. (1)		
NICKEL	0.01 (0)			. (1)		
PH	12.2 (0)			11.9 (1)		
POTASSIUM	20 (0)			. (1)		
SELENIUM	0.06 (0)			. (1)		
SILICON	0.65 (0)			. (1)		
SILVER	0.0025 (0)			. (1)		
SODIUM	3.73 (0)			. (1)		
SO4	1570 (0)			1100 (1)		
STRONTIUM	1.82 (0)			. (1)		
TDS	3650 (0)			2220 (1)		
TITANIUM	100E-5 (0)			. (1)		
TOC	3.7 (0)			. (1)		
URANIUM	0.15 (0)			. (1)		
VANADIUM	0.005 (0)			. (1)		
ZINC	0.323 (0)			. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.768 (0)			• (1)		
ARSENIC	0.04 (0)			• (1)		
BARIUM	0.283 (0)			• (1)		
BORON	12.3 (0)			• (1)		
CADMIUM	0.0025 (0)			• (1)		
CALCIUM	1120 (0)			• (1)		
CHROMIUM	0.0025 (0)			• (1)		
CL	8.62 (0)			• (1)		
COBALT	0.075 (0)			• (1)		
COND	24700 (0)			4880 (1)		
COPPER	0.0025 (0)			• (1)		
F	0.968 (0)			0.495 (1)		
IRON	0.264 (0)			• (1)		
LEAD	0.035 (0)			• (1)		
LITHIUM	• (0)			• (1)		
MAGNESIUM	0.865 (0)			• (1)		
MANGANESE	500E-6 (0)			• (1)		
MERCURY	• (0)			• (1)		
NICKEL	0.01 (0)			• (1)		
PH	12.2 (0)			12.1 (1)		
POTASSIUM	20 (0)			• (1)		
SELENIUM	0.06 (0)			• (1)		
SILICON	0.65 (0)			• (1)		
SILVER	0.0025 (0)			• (1)		
SODIUM	3.73 (0)			• (1)		
SO4	1570 (0)			965 (1)		
STRONTIUM	1.82 (0)			• (1)		
TDS	3650 (0)			2350 (1)		
TITANIUM	100E-5 (0)			• (1)		
TOC	3.7 (0)			• (1)		
URANIUM	0.15 (0)			• (1)		
VANADIUM	0.005 (0)			• (1)		
ZINC	0.323 (0)			• (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 2 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.768 (0)			. (1)		
ARSENIC	0.04 (0)			. (1)		
BARIUM	0.283 (0)			. (1)		
BORON	12.3 (0)			. (1)		
CADMIUM	0.0025 (0)			. (1)		
CALCIUM	1120 (0)			. (1)		
CHROMIUM	0.0025 (0)			. (1)		
CL	8.62 (0)			. (1)		
COBALT	0.075 (0)			. (1)		
COND	24700 (0)			5550 (1)		
COPPER	0.0025 (0)			. (1)		
F	0.968 (0)			0.835 (1)		
IRON	0.264 (0)			. (1)		
LEAD	0.035 (0)			. (1)		
LITHIUM	. (0)			. (1)		
MAGNESIUM	0.865 (0)			. (1)		
MANGANESE	500E-6 (0)			. (1)		
MERCURY	. (0)			. (1)		
NICKEL	0.01 (0)			. (1)		
PH	12.2 (0)			12.2 (1)		
POTASSIUM	20 (0)			. (1)		
SELENIUM	0.06 (0)			. (1)		
SILICON	0.65 (0)			. (1)		
SILVER	0.0025 (0)			. (1)		
SODIUM	3.73 (0)			. (1)		
SO4	1570 (0)			975 (1)		
STRONTIUM	1.82 (0)			. (1)		
TDS	3650 (0)			2490 (1)		
TITANIUM	100E-5 (0)			. (1)		
TOC	3.7 (0)			. (1)		
URANIUM	0.15 (0)			. (1)		
VANADIUM	0.005 (0)			. (1)		
ZINC	0.323 (0)			. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP

• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SHALE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	0.288 (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	0.04 (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	0.0859 (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	0.0996 (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	1350 (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	0.169 (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	6.75 (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	0.075 (1)		
COND.	10900 (0)	8250(1) 3940(2)	11000(1)	5200 (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	0.37 (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	0.324 (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	0.035 (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	0.0927 (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	.00344 (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY SHALE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
		.(2)				
NICKEL	0.01 (0)	0.01(1) 0.01(2)	0.01(1)	0.0669 (1)		
PH	12 (0)	12.2(1) 11.8(2)	12.3(1)	12 (1)		
POTASSIUM	20 (0)	20(1) 20(2)	20(1)	20 (1)		
SELENIUM	0.06 (0)	0.06(1) 0.06(2)	0.06(1)	0.06 (1)		
SILICON	1.22 (0)	0.827(1) 0.964(2)	0.602(1)	1.46 (1)		
SILVER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
SODIUM	2.5 (0)	2.5(1) 16.6(2)	11.6(1)	20 (1)		
SO4	1590 (0)	1260(1) 1380(2)	1450(1)	955 (1)		
STRONTIUM	1.39 (0)	1.36(1) 0.81(2)	4.6(1)	3.3 (1)		
TDS	3800 (0)	3700(1) 2330(2)	3140(1)	1780 (1)		
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2)	100E-5(1)	100E-5 (1)		
TOC	1.58 (0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15 (0)	0.15(1) 0.15(2)	0.15(1)	0.15 (1)		
VANADIUM	0.005 (0)	0.005(1) 0.005(2)	0.005(1)	0.005 (1)		
ZINC	0.496 (0)	0.258(1) 0.0478(2)	0.475(1)	0.174 (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	0.346 (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	0.04 (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	0.0782 (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	4.3 (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	1830 (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	0.0025 (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	2.7 (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	0.075 (1)		
COND	10900 (0)	8250(1) 3940(2)	11000(1)	5400 (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	0.84 (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	0.168 (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	0.035 (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	0.0643 (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	500E-6 (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL

(LEACHING FROM PFBC WASTE AND ATTENUATION BY INTERBURDEN LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
		.(2)				
NICKEL	0.01 (0)	0.01(1) 0.01(2)	0.01(1)	0.01 (1)		
PH	12 (0)	12.2(1) 11.8(2)	12.3(1)	12 (1)		
POTASSIUM	20 (0)	20(1) 20(2)	20(1)	20 (1)		
SELENIUM	0.06 (0)	0.06(1) 0.06(2)	0.06(1)	0.06 (1)		
SILICON	1.22 (0)	0.827(1) 0.964(2)	0.602(1)	1.37 (1)		
SILVER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
SODIUM	2.5 (0)	2.5(1) 16.6(2)	11.6(1)	5.34 (1)		
SO4	1590 (0)	1260(1) 1380(2)	1450(1)	1270 (1)		
STRONTIUM	1.39 (0)	1.36(1) 0.81(2)	4.6(1)	4.2 (1)		
TDS	3800 (0)	3700(1) 2330(2)	3140(1)	2660 (1)		
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2)	100E-5(1)	100E-5 (1)		
TOC	1.58 (0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15 (0)	0.15(1) 0.15(2)	0.15(1)	0.15 (1)		
VANADIUM	0.005 (0)	0.005(1) 0.005(2)	0.005(1)	0.005 (1)		
ZINC	0.496 (0)	0.258(1) 0.0478(2)	0.475(1)	0.286 (1)		

* NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	0.348 (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	0.04 (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	0.0677 (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	2.74 (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 [illegible]		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	1870 (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	0.0143 (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	5.25 (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	0.075 (1)		
COND	10900 (0)	8250(1) 3940(2)	11000(1)	6450 (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	0.495 (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	0.207 (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	0.035 (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	0.0688 (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	500E-6 (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
. LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY SANDSTONE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP						
	STEP 1		STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
			.(2)				
NICKEL	0.01	(0)	0.01(1) 0.01(2)	0.01(1)	0.01 (1)		
PH	12	(0)	12.2(1) 11.8(2)	12.3(1)	12.1 (1)		
POTASSIUM	20	(0)	20(1) 20(2)	20(1)	20 (1)		
SELENIUM	0.06	(0)	0.06(1) 0.06(2)	0.06(1)	0.06 (1)		
SILICON	1.22	(0)	0.827(1) 0.964(2)	0.602(1)	1.27 (1)		
SILVER	0.0025	(0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
SODIUM	2.5	(0)	2.5(1) 16.6(2)	11.6(1)	11.7 (1)		
SO4	1590	(0)	1260(1) 1380(2)	1450(1)	1190 (1)		
STRONTIUM	1.39	(0)	1.36(1) 0.81(2)	4.6(1)	4.1 (1)		
TDS	3800	(0)	3700(1) 2330(2)	3140(1)	2760 (1)		
TITANIUM	100E-5	(0)	100E-5(1) 100E-5(2)	100E-5(1)	100E-5 (1)		
TOC	1.58	(0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15	(0)	0.15(1) 0.15(2)	0.15(1)	0.15 (1)		
VANADIUM	0.005	(0)	0.005(1) 0.005(2)	0.005(1)	0.005 (1)		
ZINC	0.496	(0)	0.258(1) 0.0478(2)	0.475(1)	0.245 (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	0.356 (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	0.04 (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	0.127 (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	7.93 (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	1930 (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	0.0025 (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	. (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	0.075 (1)		
COND	10900 (0)	8250(1) 3940(2)	11000(1)	. (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	. (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	0.159 (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	0.035 (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	0.0836 (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	500E-6 (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFRC WASTE AND ATTENUATION BY GREERLIMESTONE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
		.(2)				
NICKEL	0.01 (0)	0.01(1) 0.01(2)	0.01(1)	0.01 (1)		
PH	12 (0)	12.2(1) 11.8(2)	12.3(1)	. (1)		
POTASSIUM	20 (0)	20(1) 20(2)	20(1)	20 (1)		
SELENIUM	0.06 (0)	0.06(1) 0.06(2)	0.06(1)	0.06 (1)		
SILICON	1.22 (0)	0.827(1) 0.964(2)	0.602(1)	1.44 (1)		
SILVER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	0.0025 (1)		
SODIUM	2.5 (0)	2.5(1) 16.6(2)	11.6(1)	27.4 (1)		
SO4	1590 (0)	1260(1) 1380(2)	1450(1)	. (1)		
STRONTIUM	1.39 (0)	1.36(1) 0.81(2)	4.6(1)	5.57 (1)		
TDS	3800 (0)	3700(1) 2330(2)	3140(1)	. (1)		
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2)	100E-5(1)	100E-5 (1)		
TOC	1.58 (0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15 (0)	0.15(1) 0.15(2)	0.15(1)	0.15 (1)		
VANADIUM	0.005 (0)	0.005(1) 0.005(2)	0.005(1)	0.005 (1)		
ZINC	0.496 (0)	0.258(1) 0.0478(2)	0.475(1)	0.248 (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	. (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	. (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	. (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	. (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	. (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	. (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	. (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	. (1)		
COND	10900 (0)	8250(1) 3940(2)	11000(1)	4090 (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	0.785 (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	. (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	. (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	. (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	. (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY GLACIAL TILL LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP STEP 1		STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
			.(2)				
NICKEL	0.01	(0)	0.01(1) 0.01(2)	0.01(1)	. (1)		
PH	12	(0)	12.2(1) 11.8(2)	12.3(1)	12 (1)		
POTASSIUM	20	(0)	20(1) 20(2)	20(1)	. (1)		
SELENIUM	0.06	(0)	0.06(1) 0.06(2)	0.06(1)	. (1)		
SILICON	1.22	(0)	0.827(1) 0.964(2)	0.602(1)	. (1)		
SILVER	0.0025	(0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
SODIUM	2.5	(0)	2.5(1) 16.6(2)	11.6(1)	. (1)		
SO4	1590	(0)	1260(1) 1380(2)	1450(1)	1160 (1)		
STRONTIUM	1.39	(0)	1.36(1) 0.81(2)	4.6(1)	. (1)		
TDS	3800	(0)	3700(1) 2330(2)	3140(1)	2430 (1)		
TITANIUM	100E-5	(0)	100E-5(1) 100E-5(2)	100E-5(1)	. (1)		
TOC	1.58	(0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15	(0)	0.15(1) 0.15(2)	0.15(1)	. (1)		
VANADIUM	0.005	(0)	0.005(1) 0.005(2)	0.005(1)	. (1)		
ZINC	0.496	(0)	0.258(1) 0.0478(2)	0.475(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PERC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	. (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	. (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	. (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	. (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	. (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	. (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	. (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	. (1)		
COND	10900 (0)	8250(1) 3940(2)	11000(1)	5200 (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	0.53 (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	. (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	. (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	. (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	. (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY ALLUVIUM LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
		.(2)				
NICKEL	0.01 (0)	0.01(1) 0.01(2)	0.01(1)	. (1)		
PH	12 (0)	12.2(1) 11.8(2)	12.3(1)	12.1 (1)		
POTASSIUM	20 (0)	20(1) 20(2)	20(1)	. (1)		
SELENIUM	0.06 (0)	0.06(1) 0.06(2)	0.06(1)	. (1)		
SILICON	1.22 (0)	0.827(1) 0.964(2)	0.602(1)	. (1)		
SILVER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
SODIUM	2.5 (0)	2.5(1) 16.6(2)	11.6(1)	. (1)		
SO4	1590 (0)	1260(1) 1380(2)	1450(1)	1050 (1)		
STRONTIUM	1.39 (0)	1.36(1) 0.81(2)	4.6(1)	. (1)		
TDS	3800 (0)	3700(1) 2330(2)	3140(1)	2710 (1)		
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2)	100E-5(1)	. (1)		
TOC	1.58 (0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15 (0)	0.15(1) 0.15(2)	0.15(1)	. (1)		
VANADIUM	0.005 (0)	0.005(1) 0.005(2)	0.005(1)	. (1)		
ZINC	0.496 (0)	0.258(1) 0.0478(2)	0.475(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
• LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
ALUMINUM	0.949 (0)	0.582(1) 0.302(2)	0.646(1)	. (1)		
ARSENIC	0.04 (0)	0.04(1) 0.04(2)	0.04(1)	. (1)		
BARIUM	0.183 (0)	0.219(1) 0.11(2)	0.161(1)	. (1)		
BORON	8.08 (0)	5.82(1) 14.6(2)	22.2(1)	. (1)		
CADMIUM	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
CALCIUM	1460 (0)	1930(1) 1160(2)	1360(1)	. (1)		
CHROMIUM	0.0025 (0)	0.0025(1) 0.0217(2)	0.0025(1)	. (1)		
CL	4.92 (0)	1.03(1) .(2)	51(1)	. (1)		
COBALT	0.075 (0)	0.075(1) 0.075(2)	0.075(1)	. (1)		
COND	10900 (0)	8250(1) 3940(2)	11000(1)	5760 (1)		
COPPER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
F	1.09 (0)	0.43(1) 0.57(2)	1.21(1)	0.63 (1)		
IRON	0.344 (0)	0.238(1) 0.183(2)	0.213(1)	. (1)		
LEAD	0.035 (0)	0.035(1) 0.035(2)	0.035(1)	. (1)		
LITHIUM	. (0)	.(1) .(2)	.(1)	. (1)		
MAGNESIUM	2.58 (0)	2.36(1) 1.15(2)	0.631(1)	. (1)		
MANGANESE	500E-6 (0)	500E-6(1) 500E-6(2)	500E-6(1)	. (1)		
MERCURY	. (0)	.(1)	.(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
. LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

TABLE 1 PRELIMINARY DATA ON LEACHING AND ATTENUATION FROM THE
COMPREHENSIVE LABORATORY PROTOCOL
(LEACHING FROM PFBC WASTE AND ATTENUATION BY LIMESTONE LEACHING TIME 1 DAYS)

CHEMICAL PARAMETER IN LEACHATE	LEVEL OF PARAMETER BY PROTOCOL STEP					
	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
NICKEL	0.01 (0)	.(2) 0.01(1) 0.01(2)	0.01(1)	. (1)		
PH	12 (0)	12.2(1) 11.8(2)	12.3(1)	12.2 (1)		
POTASSIUM	20 (0)	20(1) 20(2)	20(1)	. (1)		
SELENIUM	0.06 (0)	0.06(1) 0.06(2)	0.06(1)	. (1)		
SILICON	1.22 (0)	0.827(1) 0.964(2)	0.602(1)	. (1)		
SILVER	0.0025 (0)	0.0025(1) 0.0025(2)	0.0025(1)	. (1)		
SODIUM	2.5 (0)	2.5(1) 16.6(2)	11.6(1)	. (1)		
SO4	1590 (0)	1260(1) 1380(2)	1450(1)	975 (1)		
STRONTIUM	1.39 (0)	1.36(1) 0.81(2)	4.6(1)	. (1)		
TDS	3800 (0)	3700(1) 2330(2)	3140(1)	2720 (1)		
TITANIUM	100E-5 (0)	100E-5(1) 100E-5(2)	100E-5(1)	. (1)		
TOC	1.58 (0)	.(1) .(2)	.(1)	. (1)		
URANIUM	0.15 (0)	0.15(1) 0.15(2)	0.15(1)	. (1)		
VANADIUM	0.005 (0)	0.005(1) 0.005(2)	0.005(1)	. (1)		
ZINC	0.496 (0)	0.258(1) 0.0478(2)	0.475(1)	. (1)		

+ NUMBER IN PARENTHESES AFTER LEVEL VALUE INDICATES THE PARTICULAR REPETITION OF THE STEP
* LEVELS ARE REPORTED AS LEACHATE CONCENTRATIONS IN PPM

FIELD DATA LISTING

```
PARAMETER=AL

SAMPLE PT MONTH DAY YEAR  CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ----  ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4  79    0.213   0.116   0.326   0.124   0.384   0.744       .        .
    L        8    4  79   0.0934   0.122  0.0726    0.13   -0.06   0.271   0.085    -0.06
    U        8    6  79    0.396    0.13   0.283   0.145  0.0623    0.43       .        .
    L        8    6  79    0.208   0.272       .   0.131   -0.06   0.191   0.125    -0.06
    U        8    7  79    -0.06   0.107  0.0755   -0.06  0.0708   -0.06       .        .
    L        8    7  79    0.181  0.0898       .  0.0841   -0.06   0.213   0.124    -0.06
    U        8    8  79        .   0.139       .   0.126       .       .       .        .
    L        8    8  79   0.0831  0.0822       .  0.0907   -0.06   0.123   -0.06    -0.06
    U        8   11  79   0.0831   0.163  0.0812   -0.06   -0.06  0.0604       .        .
    L        8   11  79    0.188   0.121   -0.06   -0.06   -0.06   0.231   0.123    -0.06
    U        8   12  79   0.0812   0.132   0.131     0.1  0.0869  0.0755       .        .
    L        8   12  79    0.279   0.139   -0.06  0.0955   -0.06   0.206   0.205    -0.06
    U        8   14  79   0.0694   0.097   0.133   -0.06  0.0659  0.0641       .        .
    L        8   14  79   0.0748   -0.06  0.0721  0.0792   -0.06   0.209   0.126   0.0828
    U        8   16  79    0.105  0.0925  0.0899   -0.06   0.097   0.113       .        .
    L        8   16  79    -0.06  0.0703   -0.06  0.0943  0.0961   0.189   0.089    -0.06
    U        8   19  79   0.0774   0.139   0.134  0.0783  0.0774  0.0783       .        .
    L        8   19  79    0.112   0.129   0.081   0.102   -0.06   0.163   -0.06    -0.06
    U        8   24  79   0.0632   -0.06   -0.06   -0.06   -0.06   -0.06       .        .
    L        8   24  79    -0.06   -0.06   -0.06   -0.06   -0.06   0.133  0.0668    -0.06
    U        8   28  79    0.289   0.261   0.349   0.338   0.364    0.38       .        .
    L        8   28  79     0.23   0.195   0.364   0.374   0.299   0.392   0.333    0.121
    U        9    2  79    0.234   0.239   0.382   0.329   0.369   0.386       .        .
    L        9    2  79    0.253   0.388   0.376   0.422   0.297   0.445   0.483    0.176
    U        9    9  79    0.412   0.418   0.403   0.386    0.33   0.319       .        .
    L        9    9  79    0.374    0.37   0.347   0.314   0.197   0.389   0.398        .
    U        9   20  79    0.149   0.192   0.177   0.112  0.0923   0.191       .        .
    L        9   20  79    0.121   0.109   0.125   0.132    0.09   0.191   0.108    -0.06
    U        9   29  79   0.0915   0.109  0.0947   -0.06  0.0797    0.13       .        .
    L        9   29  79   0.0836   0.108   -0.06  0.0749  0.0812    0.15   0.141    -0.06
    U       10   14  79        .       .       .       .       .       .       .        .
    L       10   14  79        .       .       .       .       .       .       .        .
```

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PARAMETER=BA

SAMPLE PT MONTH DAY YEAR   CELL 1   CELL 2   CELL 3   CELL 4   CELL 5   CELL 6   CELL 7   CELL 12
--------- ----- --- ----   ------   ------   ------   ------   ------   ------   ------   -------
    U        8    4   79    0.201    0.181    0.109    0.208    0.203    0.059        .        .
    L        8    4   79    0.427    0.175     0.55   0.0842    0.455   0.0278   0.0874   0.0515
    U        8    6   79   0.0435   0.0566   0.0341   0.0666    0.045   0.0575        .        .
    L        8    6   79   0.0708   0.0383        .   -0.001   0.0588   -0.001   -0.001   0.0345
    U        8    7   79   0.0428   0.0604   0.0212   0.0449    0.103   0.0186        .        .
    L        8    7   79   0.0278   0.0162        .   0.0107   0.0336   -0.001   -0.001    0.069
    U        8    8   79        .   0.0672        .    0.122        .        .        .        .
    L        8    8   79   0.0177   0.0105        .   -0.001   0.0318   -0.001   -0.001   0.0415
    U        8   11   79   0.0517   0.0549   .00777   0.0605   0.0214   0.0376        .        .
    L        8   11   79   0.0054   -0.001    0.395   -0.001   0.0485   -0.001   -0.001   0.0458
    U        8   12   79   0.0328   0.0506   -0.001   0.0401   0.0203   0.0509        .        .
    L        8   12   79   -0.001   -0.001    0.175   -0.001   0.0454   -0.001   -0.001   0.0495
    U        8   14   79   0.0207   0.0599    0.039   .00676    0.026    0.042        .        .
    L        8   14   79   .00867   0.0102    0.168   -0.001   0.0249   -0.001   -0.001   0.0788
    U        8   16   79   0.0161    0.051   -0.001   0.0401   0.0224   0.0457        .        .
    L        8   16   79   -0.001   0.0193   0.0941   -0.001    0.114   -0.001   -0.001   0.0865
    U        8   19   79   0.0432     0.04   .00662   0.0366    0.013   0.0457        .        .
    L        8   19   79   0.0267   -0.001    0.063   -0.001     0.11   -0.001   .00252    0.102
    U        8   24   79   0.0161   -0.001   0.0162   0.0389   0.0282   0.0343        .        .
    L        8   24   79   .00524   -0.001   0.0634   -0.001   0.0977   -0.001   0.0379    0.111
    U        8   28   79    0.242    0.179     0.23    0.217    0.243    0.246        .        .
    L        8   28   79    0.139    0.141    0.288    0.216    0.271    0.218    0.154    0.236
    U        9    2   79    0.166    0.179    0.214    0.222    0.238     0.23        .        .
    L        9    2   79     0.15    0.205    0.284    0.239    0.256      0.2    0.234    0.228
    U        9    9   79     0.23    0.234    0.202    0.212    0.187    0.183        .        .
    L        9    9   79    0.221    0.231    0.276    0.152    0.194    0.128    0.149        .
    U        9   20   79    0.139    0.145    0.134    0.134    0.158    0.149        .        .
    L        9   20   79    0.116    0.101    0.132   0.0979    0.166   0.0951   0.0783    0.164
    U        9   29   79    0.125     0.12    0.119    0.125    0.149    0.143        .        .
    L        9   29   79   0.0971    0.103    0.125   0.0911    0.157   0.0783   0.0918    0.145
    U       10   14   79        .        .        .        .        .        .        .        .
    L       10   14   79        .        .        .        .        .        .        .        .
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PARAMETER=8

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79   16.8    19.9    21.6    20.9    9.19      18       .        .
    L         8   4   79  0.759    2.87    1.18    6.44    0.44    1.73  0.0938   0.0456
    U         8   6   79   23.8    13.4    17.8    24.3    8.27    14.4       .        .
    L         8   6   79  0.309    2.36       .    11.2  0.0779    2.63  -0.004   -0.004
    U         8   7   79   22.1    11.5    20.6    20.3    5.05    11.3       .        .
    L         8   7   79  0.273    1.71       .    7.29  0.0383    2.01  -0.004   -0.004
    U         8   8   79      .    9.67       .    19.1       .       .       .        .
    L         8   8   79  0.143     1.4       .    6.62   0.122    1.63  -0.004   -0.004
    U         8  11   79     15    8.36    16.3    14.7    4.75     8.6       .        .
    L         8  11   79   0.17    1.58   0.283    8.74  -0.004    1.55  -0.004   -0.004
    U         8  12   79   12.2    8.51    13.9      11    3.61    6.23       .        .
    L         8  12   79  0.147    1.66  -0.004    9.83  -0.004    1.95  -0.004   -0.004
    U         8  14   79   12.3    10.4    13.8    11.6    3.64    6.68       .        .
    L         8  14   79  0.455    1.92   0.327    7.26   0.242    1.88   0.161    0.114
    U         8  16   79   13.5    11.4    14.7    12.3    4.88    7.77       .        .
    L         8  16   79  0.383    1.52   0.206    5.85   0.388    1.75   0.103    0.104
    U         8  19   79   8.33    6.13      11     7.6    6.79    4.97       .        .
    L         8  19   79  0.546     1.8   0.127    5.19   0.495    1.56  0.0989   0.0963
    U         8  24   79   6.35    2.29    10.8     5.3    4.91    4.81       .        .
    L         8  24   79  0.452    1.45   0.166     5.2   0.531     1.5   0.139    0.106
    U         8  28   79   7.45    5.08    9.44    6.52    4.29    4.32       .        .
    L         8  28   79  0.771    2.27   0.736    7.86    1.65    2.34    0.18    0.132
    U         9   2   79   7.68    5.68    9.81    7.35    4.62    4.88       .        .
    L         9   2   79  0.773    2.46   0.879    7.05    1.46    2.33   0.436    0.129
    U         9   9   79   7.43    7.31    11.1     6.6    4.54    4.85       .        .
    L         9   9   79   1.14    2.32    1.05    5.28    0.83    1.73   0.182        .
    U         9  20   79   6.43    7.02    9.11    4.97    4.19    3.96       .        .
    L         9  20   79  0.619    1.31   0.474    4.31   0.749    1.44  0.0633   0.0363
    U         9  29   79    5.8    5.37    8.52    5.29    4.74    4.39       .        .
    L         9  29   79    1.2    2.47   0.857    3.97   0.785    2.27     0.1    0.042
    U        10  14   79      .       .       .       .       .       .       .        .
    L        10  14   79      .       .       .       .       .       .       .        .
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PARAMETER=CD

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79 0.0182  -0.005   0.026  -0.005  -0.005  .00538       .        .
    L        8    4   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8    6   79 .00664  -0.005  0.0183  0.0055  -0.005  -0.005       .        .
    L        8    6   79 -0.005  -0.005       .  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8    7   79 0.0064  -0.005   0.011  .00658  -0.005  -0.005       .        .
    L        8    7   79 -0.005  -0.005       .  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8    8   79      .  -0.005       .  -0.005       .       .       .        .
    L        8    8   79 -0.005  -0.005       .  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   11   79 -0.005  -0.005  .00825  -0.005  -0.005  -0.005       .        .
    L        8   11   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  0.00536
    U        8   12   79 -0.005  -0.005  -0.005  -0.005  .00547  -0.005       .        .
    L        8   12   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  0.00745
    U        8   14   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   14   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   16   79 -0.005  -0.005  .00673  -0.005  -0.005  -0.005       .        .
    L        8   16   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   19   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   19   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  0.00557
    U        8   24   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   24   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   28   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   28   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        9    2   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9    2   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        9    9   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9    9   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005        .
    U        9   20   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9   20   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        9   29   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9   29   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
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PARAMETER=CA

SAMPLF PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4  79     280     354     201     323     340     336       .        .
    L        8    4  79     262     656     188     532     127     466     598     52.6
    U        8    6  79     244     328     334     246     143     357       .        .
    L        8    6  79     798     672       .     393    37.1     470     627     26.6
    U        8    7  79     219     308     209     163     200     264       .        .
    L        8    7  79     734     591       .     459    32.6     478     639     19.2
    U        8    8  79       .     406       .     198       .       .       .        .
    L        8    8  79     702     527     317     459    37.7     462     634       27
    U        8   11  79     362     443     209     283     204     360       .        .
    L        8   11  79     705     511     312     446    27.2     467     669      133
    U        8   12  79     337     463     228     320     232     437       .        .
    L        8   12  79     695     519     313     419    29.5     456     681     53.2
    U        8   14  79     352     429     374     306     254     430       .        .
    L        8   14  79     711     505     312     437    60.4     471     668     21.1
    U        8   16  79     360     390     414     306     249     380       .        .
    L        8   16  79     677     488     359     439    59.5     472     664     33.9
    U        8   19  79     406     435     422     376     261     438       .        .
    L        8   19  79     635     479     350     437    75.4     480     665       23
    U        8   24  79     433     351     468     420     332     450       .        .
    L        8   24  79     604     459     425     424    95.4     465     659     23.1
    U        8   28  79     464     496     672     496     432     556       .        .
    L        8   28  79     664     526     400     494     359     524     787     27.5
    U        9    2  79     439     474     646     425     422     533       .        .
    L        9    2  79     657     516     404     485     366     510     795      101
    U        9    9  79     463     462     588     429     440     524       .        .
    L        9    9  79     651     506     413     480     101     498     822        .
    U        9   20  79     420     435     517     401     416     502       .        .
    L        9   20  79     654     499     319     455     178     475     777     47.1
    U        9   29  79     406     461     506     386     385     465       .        .
    L        9   29  79     558     453       .     427     168     428     787     40.1
    U       10   14  79       .       .       .       .       .       .       .        .
    L       10   14  79       .       .       .       .       .       .       .        .
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PARAMETER=CR

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U       8    4   79   0.493   0.345   0.308    0.33   0.325   0.325       .        .
    L       8    4   79  0.0848   0.125  0.0639   0.118  0.0116   0.151  0.0402   -0.005
    U       8    6   79   0.253   0.156   0.249   0.211   0.273  0.0884       .        .
    L       8    6   79   0.082  0.0931       .  0.0991  -0.005   0.129  0.0578   -0.005
    U       8    7   79   0.149  0.0956   0.147  0.0556    0.14  0.0297       .        .
    L       8    7   79  0.0739   0.067       .    0.07  -0.005   0.128  0.0564   -0.005
    U       8    8   79       .  0.0688       .  0.0751       .       .       .        .
    L       8    8   79  0.0583  0.0584       .  0.0725  -0.005   0.117  0.0485   -0.005
    U       8   11   79  0.0659  0.0669  0.0984  0.0594  0.0878   0.042       .        .
    L       8   11   79  0.0728  0.0678   0.017  0.0697  -0.005    0.13  0.0596   0.0111
    U       8   12   79   0.044  0.0546  0.0618    0.04  0.0474  0.0394       .        .
    L       8   12   79  0.0878  0.0714  0.0258  0.0623  -0.005   0.127  0.0682   -0.005
    U       8   14   79  0.0529   0.053  0.0927   0.041  0.0203  0.0406       .        .
    L       8   14   79  0.0629  0.0573  0.0421  0.0566  .00872   0.129  0.0545   -0.005
    U       8   16   79   0.116  0.0666   0.117  0.0567  0.0241  0.0549       .        .
    L       8   16   79  0.0617  0.0602  0.0543  0.0665  0.0061   0.122  0.0528   -0.005
    U       8   19   79  0.0788  0.0932  0.0979  0.0822  0.0207   0.103       .        .
    L       8   19   79  0.0686  0.0679  0.0582  0.0683  .00834   0.129  0.0545   -0.005
    U       8   24   79  0.0808  0.0547   0.101  0.0891  0.0157  0.0984       .        .
    L       8   24   79  0.0612  0.0609  0.0598  0.0648  0.0062    0.12  0.0518   -0.005
    U       8   28   79  0.0626  0.0636  0.0498   0.109   0.031   0.132       .        .
    L       8   28   79  0.0849  0.0759  0.0919    0.08  0.0666   0.131  0.0774   -0.005
    U       9    2   79  0.0587  0.0548  0.0567  0.0832  0.0279  0.0981       .        .
    L       9    2   79  0.0835  0.0833  0.0878  0.0925  0.0739   0.138  0.0828   0.0115
    U       9    9   79  0.0954  0.0915    0.11   0.109  0.0476   0.113       .        .
    L       9    9   79  0.0863  0.0831  0.0844  0.0916  0.0346   0.138  0.0858        .
    U       9   20   79  0.0819  0.0863   0.104  0.0861  0.0267   0.118       .        .
    L       9   20   79  0.0652  0.0657  0.0656  0.0704  0.0274   0.104   0.059   -0.005
    U       9   29   79  0.0684  0.0697  0.0855   0.064  0.0347   0.095       .        .
    L       9   29   79  0.0647  0.0638  0.0599  0.0653  0.0254  0.0914  0.0635   -0.005
    U      10   14   79       .       .       .       .       .       .       .        .
    L      10   14   79       .       .       .       .       .       .       .        .
```

```
PARAMETER=CL

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U       8    4   79      .      323     493       .       .       .       .       .
    L       8    4   79      .      160       .     316     127       .       .       .
    U       8    6   79    252      179     391     290       .       .       .       .
    L       8    6   79    117      160       .     265       .       .       .       .
    U       8    7   79    160      124     305     190       .       .       .       .
    L       8    7   79    103      165       .     339       .       .       .       .
    U       8    8   79      .        .       .       .       .       .       .       .
    L       8    8   79      .      173       .       .       .       .       .       .
    U       8   11   79    209       99     241     216       .       .       .       .
    L       8   11   79    130      149     122     362      18       .       .       .
    U       8   12   79    180       95     146     155       .       .       .       .
    L       8   12   79    142      136      48     267      21       .       .       .
    U       8   14   79    169      125     166     146       .       .       .       .
    L       8   14   79    117      132      62     302      37       .       .       .
    U       8   16   79      .        .     189     151       .       .       .       .
    L       8   16   79    120      138     142     320      36       .       .       .
    U       8   19   79    174       94     164      99       .       .       .       .
    L       8   19   79    125      131     151     346      39       .       .       .
    U       8   24   79      .        .       .       .       .       .       .       .
    L       8   24   79      .        .       .       .       .       .       .       .
    U       8   28   79      .        .       .       .       .       .       .       .
    L       8   28   79      .        .       .       .       .       .       .       .
    U       9    2   79      .        .       .       .       .       .       .       .
    L       9    2   79      .        .       .       .       .       .       .       .
    U       9    9   79      .        .       .       .       .       .       .       .
    L       9    9   79      .        .       .       .       .       .       .       .
    U       9   20   79      .        .       .       .       .       .       .       .
    L       9   20   79      .        .       .       .       .       .       .       .
    U       9   29   79      .        .       .       .       .       .       .       .
    L       9   29   79      .        .       .       .       .       .       .       .
    U      10   14   79      .        .       .       .       .       .       .       .
    L      10   14   79      .        .       .       .       .       .       .       .
```

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PARAMETER=CO

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79   0.218   0.161   0.176   -0.15   0.237   0.181       .        .
    L         8   4   79   0.283   0.207   -0.15   0.223   -0.15    1.07   0.156    -0.15
    U         8   6   79   -0.15   0.297   0.299   -0.15   -0.15   0.167       .        .
    L         8   6   79   0.482   0.554       .   0.269   -0.15    0.67   0.367    -0.15
    U         8   7   79   -0.15   0.311   0.206   -0.15    0.16   -0.15       .        .
    L         8   7   79   0.434   0.314       .   0.223   -0.15   0.644   0.334    -0.15
    U         8   8   79       .   0.224       .   0.169       .       .       .        .
    L         8   8   79   0.236   0.197       .   0.224   -0.15   0.509   0.219    -0.15
    U         8  11   79   0.237   0.394   0.229   -0.15   0.171   0.167       .        .
    L         8  11   79   0.451   0.338   -0.15    0.22   -0.15   0.645   0.362    -0.15
    U         8  12   79   0.284   0.395   0.318   0.254   0.248   0.231       .        .
    L         8  12   79   0.654   0.389   -0.15   0.267   -0.15    0.61   0.475    -0.15
    U         8  14   79   -0.15   -0.15   -0.15   -0.15   -0.15   -0.15       .        .
    L         8  14   79   -0.15   -0.15   -0.15   -0.15   -0.15   0.404   -0.15    -0.15
    U         8  16   79   -0.15   -0.15   -0.15   -0.15   -0.15   -0.15       .        .
    L         8  16   79   -0.15   -0.15   -0.15   -0.15   -0.15   0.325   -0.15    -0.15
    U         8  19   79   -0.15   -0.15   -0.15   -0.15   -0.15   -0.15       .        .
    L         8  19   79   -0.15   -0.15   -0.15   -0.15   -0.15   0.402   -0.15    -0.15
    U         8  24   79   -0.15   -0.15   -0.15   -0.15   -0.15   -0.15       .        .
    L         8  24   79   -0.15   -0.15   -0.15   -0.15   -0.15   0.289   -0.15    -0.15
    U         8  28   79    0.18   0.249   0.251   0.197   0.291   0.269       .        .
    L         8  28   79   0.219   0.192   0.249   0.188   0.175   0.386    0.38    -0.15
    U         9   2   79   0.187   0.242    0.28   0.216   0.256   0.236       .        .
    L         9   2   79   0.246   0.253   0.224   0.277   0.177   0.435   0.442    -0.15
    U         9   9   79    0.27    0.26   0.228   0.186   0.261   0.241       .        .
    L         9   9   79   0.248   0.196   -0.15   0.188   -0.15   0.361   0.397        .
    U         9  20   79   -0.15   0.169   -0.15   -0.15   -0.15   -0.15       .        .
    L         9  20   79   -0.15   -0.15   -0.15   -0.15   -0.15   0.205   -0.15    -0.15
    U         9  29   79   -0.15   -0.15   -0.15   -0.15   -0.15   -0.15       .        .
    L         9  29   79   -0.15   -0.15   -0.15   -0.15   -0.15   0.154   -0.15    -0.15
    U        10  14   79       .       .       .       .       .       .       .        .
    L        10  14   79       .       .       .       .       .       .       .        .
```

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PARAMETER=CNDT

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79  38000   22000   47000   28400   30000   40000       .        .
    L         8   4   79      .    6700       .   22300       .   11500    2790        .
    U         8   6   79  20000   15200   37200   25000   18000   11000       .        .
    L         8   6   79   5250    8400       .   21800     325    9500    2950      262
    U         8   7   79  18000   60000   27500   14000   11500    8000       .        .
    L         8   7   79   4900    7200       .   13500     290    8800    3380      272
    U         8   8   79      .       .       .       .       .       .       .        .
    L         8   8   79   4850    7250       .       .       .    8300    3350        .
    U         8  11   79  18000   11000   23900   14500   12500    9400       .        .
    L         8  11   79   5050    7500    1600   13500     246    8000    3400      934
    U         8  12   79  13500    9600   14200   10000   11000   10000       .        .
    L         8  12   79   5000    6900    1520   11000     265    8500    3100      459
    U         8  14   79  13500   12600   15600   11500    9500    8900       .        .
    L         8  14   79   5200    7520    2100   12000     565    8000    3150      220
    U         8  16   79      .       .   19600   12000   10500    9500       .        .
    L         8  16   79   5100    7180    2420   12000     590    7500    3150      290
    U         8  19   79  14500   11000   15000   13600   10500   10000       .        .
    L         8  19   79   5850    7000    2500   17800     815    7500    3300      205
    U         8  24   79  13500   10500   15000   12500   11500    8500       .        .
    L         8  24   79   5950    7100    3300   13500    1280    7500    3400      245
    U         8  28   79  13500    7400   10500   12500   11000   11000       .        .
    L         8  28   79   6850    7900    4200   12500    4200    7900    3530      205
    U         9   2   79  11000    7750   10000   10000   11000    9200       .        .
    L         9   2   79   6300    7600    4150   12500    5250    7500    3400      603
    U         9   9   79  11500   10000   13000   12000   10500    9700       .        .
    L         9   9   79   6500    7900    3600       .    2150    7250    3500      335
    U         9  20   79   9750   11000   14000   10000   11000   11000       .        .
    L         9  20   79   6000    7300    3900   12000    2380    7000    3700      355
    U         9  29   79   9500    7800   13000    8400    9000    9200       .        .
    L         9  29   79   6750    7600    3900   10000    2340    7500    3800      323
    U        10  14   79   5700    7300    7100    4700    5500    5400       .        .
    L        10  14   79   6100    6000    4500    6800    5250    6500    3550      195
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PARAMETER=CU

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79 0.0181  -0.005   0.019  0.0105  0.0147  0.0116       .        .
    L        8    4   79 -0.005  .00744  -0.005  .00678  -0.005  0.0207  -0.005   -0.005
    U        8    6   79 .00516  0.0098  0.0395  0.0114  0.0147  -0.005       .        .
    L        8    6   79 0.0178  0.0444       .  0.0175  -0.005  .00906  0.0087   -0.005
    U        8    7   79 -0.005  .00604  .00774  -0.005  0.0128  -0.005       .        .
    L        8    7   79 0.0154  0.0147       .  .00619  -0.005  0.0105  .00737   -0.005
    U        8    8   79      .  .00604       .  -0.005       .       .       .        .
    L        8    8   79 .00862  0.0119       .  .00589  -0.005  .00648  -0.005   -0.005
    U        8   11   79 -0.005  0.0133  .00545  -0.005   0.007  -0.005       .        .
    L        8   11   79 0.0214  0.0186  -0.005  -0.005  -0.005  .00965  .00648   -0.005
    U        8   12   79 -0.005  .00833  .00619  -0.005  .00553  -0.005       .        .
    L        8   12   79 0.0269  0.0197  -0.005  .00722  -0.005  .00811  0.0117  0.00582
    U        8   14   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   14   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   16   79 .00851  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   16   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   19   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   19   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   24   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   24   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   28   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   28   79 .00518  -0.005  0.0058  -0.005  -0.005  -0.005  .00766   -0.005
    U        9    2   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9    2   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  .00984   -0.005
    U        9    9   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9    9   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  .00681        .
    U        9   20   79 .00773  0.0101  -0.005  -0.005  -0.005  -0.005       .        .
    L        9   20   79 -0.005  -0.005  .00512  -0.005  0.0122  -0.005  -0.005   -0.005
    U        9   29   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        9   29   79 -0.005  -0.005  -0.005  -0.005  .00866  -0.005  -0.005   -0.005
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
```

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PARAMETER=F

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79    0.5    0.36    0.64    0.48    0.63    0.89       .        .
    L         8   4   79      .    0.23       .    2.38    0.28    0.39    0.22        .
    U         8   6   79    0.5    0.35    0.53    0.31    0.52    0.23       .        .
    L         8   6   79   0.17    0.18       .    2.61    0.06    0.35     0.2    -0.05
    U         8   7   79   0.34    0.29    0.46    0.33    0.34    0.22       .        .
    L         8   7   79   0.13    0.16       .    1.64    0.14    0.37    0.15     0.15
    U         8   8   79      .       .       .       .       .       .       .        .
    L         8   8   79   0.13    0.26       .       .       .    0.37    0.13        .
    U         8  11   79   0.32    0.21    0.26    0.33    0.41    0.19       .        .
    L         8  11   79   0.19    0.19    0.41    1.63    0.06    0.31    0.16     0.14
    U         8  12   79   0.25    0.38     0.2    0.31     0.3    0.26       .        .
    L         8  12   79    0.2    0.17    0.37    1.99    0.05    0.27    0.17     0.13
    U         8  14   79   0.26    0.29    0.25    0.29     0.2    0.19       .        .
    L         8  14   79   0.21    0.22    0.33    1.62    0.05    0.37    0.19     0.14
    U         8  16   79      .       .    0.26    0.35    0.28    0.25       .        .
    L         8  16   79    0.3    0.23    0.41    1.57    0.16    0.43     0.2     0.15
    U         8  19   79   0.29    0.24    0.19     0.2    0.29    0.31       .        .
    L         8  19   79   0.23    0.27    0.41    1.57     0.7    0.45     0.2      0.1
    U         8  24   79    0.3    0.22    0.19    0.31    0.22    0.31       .        .
    L         8  24   79   0.23    0.23    0.35    1.74    0.16    0.45    0.17     0.11
    U         8  28   79    0.2    0.12    0.14    0.33    0.24     0.3       .        .
    L         8  28   79   0.15     0.2     0.4    1.49    0.32    0.39    0.13     0.14
    U         9   2   79   0.27    0.49    0.13    0.25     0.2     0.2       .        .
    L         9   2   79   0.18    0.21    0.39    1.81    0.34    0.41    0.11     0.11
    U         9   9   79   0.15    0.23    0.19    0.28    0.16    0.28       .        .
    L         9   9   79   0.17    0.22    0.36    1.55    0.17    0.28    0.17     0.13
    U         9  20   79    0.3    0.25    0.21    0.23    0.22    0.29       .        .
    L         9  20   79   0.18     0.2     0.3    1.68     0.2    0.39    0.11     0.14
    U         9  29   79    0.2     0.2    0.36    0.24    0.24    0.24       .        .
    L         9  29   79   0.16    0.17    0.27    1.63     0.2    0.45    0.06     0.12
    U        10  14   79   0.21    0.29    0.25    0.29    0.21    0.23       .        .
    L        10  14   79   0.23    0.24    0.45    1.35    0.24     0.4    0.23     0.13
```

```
PARAMETER=FE

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79 0.0729  0.0224  0.0673  0.0279  0.0134  0.0366       .        .
    L        8    4   79 0.0194  0.0346  .00439  0.0382  -0.004   0.202  0.0267   0.0863
    U        8    6   79 0.0264  0.0358  0.0634  0.0291  0.0102  0.0362       .        .
    L        8    6   79 0.0409  0.0413       .  0.0421   0.128    0.12  0.0575   0.0938
    U        8    7   79 0.0307   0.013  0.0666  0.0374  -0.004  0.0169       .        .
    L        8    7   79 0.0748  0.0472       .    0.13   0.134   0.106  0.0551     0.15
    U        8    8   79      .   0.165       .  .00648       .       .       .        .
    L        8    8   79  0.087  0.0685       .  0.0338   0.126  0.0614  0.0283    0.128
    U        8   11   79 0.0283  0.0327  0.0256   0.404  .00981  0.0161       .        .
    L        8   11   79 0.0319  0.0303  0.0204  0.0299    0.13  0.0567   0.024    0.121
    U        8   12   79 0.0287  0.0244   0.024   0.625  .00745  0.0334       .        .
    L        8   12   79 0.0374   0.024  .00429  0.0271   0.141  0.0606  0.0484    0.105
    U        8   14   79 0.0297  0.0268  0.0326    1.24  0.0123  0.0565       .        .
    L        8   14   79 0.0181  0.0358  0.0228  0.0221   0.134  0.0489  0.0261    0.106
    U        8   16   79 0.0376  0.0257  0.0391    0.71  0.0102  0.0445       .        .
    L        8   16   79 0.0232  0.0254  0.0232  0.0214   0.126  0.0528  0.0235    0.102
    U        8   19   79 0.0366  0.0282  0.0369   0.124  0.0131   0.235       .        .
    L        8   19   79 0.0268  0.0308  0.0228   0.021  0.0952  0.0543  0.0282   0.0847
    U        8   24   79 0.0348  0.0199  0.0369    0.12  0.0152  0.0452       .        .
    L        8   24   79 0.0214  0.0217  0.0243  0.0286  0.0525  0.0557  0.0329   0.0499
    U        8   28   79 0.0215  0.0161  0.0155     0.2  0.0164  0.0559       .        .
    L        8   28   79 0.0221  0.0275    0.02  0.0233  0.0344  0.0422   0.026    0.017
    U        9    2   79 0.0257  0.0152  0.0233   0.211  0.0125  0.0374       .        .
    L        9    2   79 0.0245  0.0233  0.0338  0.0188  0.0203  0.0437   0.032   0.0134
    U        9    9   79 0.0371  0.0293  0.0245    0.31  0.0149  0.0401       .        .
    L        9    9   79 0.0263  0.0224   0.046  0.0254  0.0179  0.0425  0.0251        .
    U        9   20   79 0.0391  0.0417    0.04   0.118  0.0186   0.246       .        .
    L        9   20   79 0.0329    0.03  0.0347  0.0324  0.0362  0.0429  0.0233  0.00661
    U        9   29   79 0.0291   0.025  0.0297  0.0736  0.0271   0.629       .        .
    L        9   29   79 0.0204  0.0209  0.0183  0.0224  0.0207  0.0329  0.0245   -0.004
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
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PARAMETER=LI

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79   6.36    5.48    5.71    4.81    4.78    4.37       .        .
    L         8   4   79   0.84    0.38    0.69    3.63    0.47    1.84    0.23     0.76
    U         8   6   79   5.74     5.1     5.6     4.8     3.7    4.37       .        .
    L         8   6   79   0.83    0.44       .    4.65     0.1     1.9     0.2    -0.02
    U         8   7   79    5.2    3.18    5.87    4.56    3.76    3.09       .        .
    L         8   7   79   0.04    0.39       .    2.71    0.04    1.29    0.02     0.02
    U         8   8   79      .    3.27       .    4.44       .       .       .        .
    L         8   8   79   0.04    0.31       .    2.71    0.04    1.15    0.02     0.02
    U         8  11   79   5.48    2.87    5.81    4.91    4.49    3.42       .        .
    L         8  11   79   0.05    0.31    0.31    2.89    0.05    1.11    0.03     0.04
    U         8  12   79   4.75    2.73    4.37    3.95     4.3    3.09       .        .
    L         8  12   79   0.03     0.4    0.07    3.24    0.04    1.35    0.03     0.04
    U         8  14   79   3.76    2.78    4.15    3.34    3.42     2.9       .        .
    L         8  14   79   0.01     0.3    0.04    2.64    0.01    1.07    0.01     0.01
    U         8  16   79   3.82     3.1    4.08     3.6    3.78    3.08       .        .
    L         8  16   79   0.01    0.26    0.01    2.42    0.01    1.02   -0.01     0.01
    U         8  19   79    4.1     2.6    4.04    3.58    3.96    3.12       .        .
    L         8  19   79   0.01    0.34    0.02    2.14    0.01    0.96    0.01     0.01
    U         8  24   79   3.04    2.64    3.86    3.42    4.06    3.04       .        .
    L         8  24   79   0.01    0.24    0.01     2.4    0.01     0.9    0.01     0.02
    U         8  28   79    3.8    2.02    3.76    3.76    3.48       3       .        .
    L         8  28   79   0.01    0.37    0.02    3.16    0.37    0.98    0.01     0.01
    U         9   2   79    3.6    2.02     3.5     3.6     3.1    2.85       .        .
    L         9   2   79   0.01    0.44    0.05     3.4    0.34    1.07    0.01     0.01
    U         9   9   79   3.32    2.36    3.56    3.16     3.6    3.08       .        .
    L         9   9   79   0.01    0.37    0.08    2.44    0.06    0.96    0.01     0.01
    U         9  20   79   3.19    2.38    3.71    2.75    3.69    3.11       .        .
    L         9  20   79   0.03   0.234   0.061    2.57   0.087    0.93   -0.02    0.026
    U         9  29   79    2.8    1.63     3.5    2.21    3.11    2.75       .        .
    L         9  29   79   0.03   0.735   0.208    2.21   0.069    1.96   -0.02    0.026
    U        10  14   79      .       .       .       .       .       .       .        .
    L        10  14   79      .       .       .       .       .       .       .        .
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PARAMETER=MG

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79    567     218     746     389    2.97     462       .        .
    L        8    4   79   21.9     386    15.8     409   0.837     500     113     8.15
    U        8    6   79    268     141     658     298    1.56    82.8       .        .
    L        8    6   79    177     201       .     303    6.54     394     123     5.31
    U        8    7   79    146     145     391     114   0.391    52.2       .        .
    L        8    7   79    167     185       .     226    6.45     390     125     3.98
    U        8    8   79      .     146       .    20.6       .       .       .        .
    L        8    8   79    161     171       .     229      11     367     126     5.25
    U        8   11   79    119     130     284     192    2.59     107       .        .
    L        8   11   79    162     169    43.6     206    5.14     377     132     27.6
    U        8   12   79   73.5      95     133      78    2.65    78.1       .        .
    L        8   12   79    170     175    75.5     163    5.78     361     134       11
    U        8   14   79    116     109     199    97.6    2.06    91.7       .        .
    L        8   14   79    145     140     110     136    11.9     243     113      4.1
    U        8   16   79    233     133     251     129    4.95     117       .        .
    L        8   16   79    138     135     121     145    11.6     240     112     6.71
    U        8   19   79    167     196     204     177    11.4     221       .        .
    L        8   19   79    144     139     125     150    15.3     241     113     4.26
    U        8   24   79    167     113     216     196    22.1     214       .        .
    L        8   24   79    138     136     135     146    20.9     234     112     4.25
    U        8   28   79   15.8    15.4    10.3      35    3.49    45.8       .        .
    L        8   28   79   24.2    21.9    26.2    23.1    16.6    39.7    17.6    0.473
    U        9    2   79   13.7    11.2    11.1    23.4     2.7    28.3       .        .
    L        9    2   79   21.8    21.7    25.3    25.9    19.5    40.9    17.9        2
    U        9    9   79   25.7    21.8    31.6    34.4    6.73    35.6       .        .
    L        9    9   79   22.6    21.7    23.4    25.4     6.2    40.3    18.5        .
    U        9   20   79    293     280     412     343    52.9     535       .        .
    L        9   20   79    220     217     217     259    68.8     402     187     9.58
    U        9   29   79    225     225     346     228      67     390       .        .
    L        9   29   79    223     218     218     230    62.4     325     193     8.34
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
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PARAMETER=MN

SAMPLE PT MONTH DAY YEAR  CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7 CELL 12
--------- ----- --- ----  ------  ------  ------  ------  ------  ------  ------ -------
    U         8   4   79   0.789   0.307   0.368   0.111  .00402   0.689       .       .
    L         8   4   79      13    2.95    2.73   0.923    1.97    54.3    1.65    1.14
    U         8   6   79   0.934   0.639   0.923   0.153  0.0263  0.0219       .       .
    L         8   6   79    2.53    2.24       .   0.435   0.953    27.6   0.556    0.64
    U         8   7   79   0.419   0.686    0.55  0.0258  -0.001  .00415       .       .
    L         8   7   79    2.26    2.31       .    1.14   0.849    28.9   0.635   0.575
    U         8   8   79       .   0.923       .  0.0199       .       .       .       .
    L         8   8   79     2.2    2.21       .   0.908   0.942    26.6   0.618   0.616
    U         8  11   79   0.848   0.872   0.558   0.296  -0.001   0.104       .       .
    L         8  11   79    1.98    1.99    2.71    0.84   0.845    26.6   0.607   0.716
    U         8  12   79   0.499   0.991   0.233   0.277  .00201   0.181       .       .
    L         8  12   79    1.63     1.7     1.2   0.334   0.912    20.9   0.414   0.744
    U         8  14   79    1.23    2.49    1.12   0.625  -0.001   0.449       .       .
    L         8  14   79     1.8    1.66   0.872   0.548    1.57    21.8   0.373   0.682
    U         8  16   79     4.2    4.33    2.22    1.01  -0.001   0.599       .       .
    L         8  16   79     1.8    1.52   0.929   0.867    1.65      22   0.421   0.759
    U         8  19   79    1.65    1.63    1.68   0.676  0.0225   0.675       .       .
    L         8  19   79    1.56    1.12       1     1.1    2.03    21.8   0.463   0.861
    U         8  24   79    2.21    1.57    2.74   0.777   0.361    1.11       .       .
    L         8  24   79    1.32   0.935   0.995    1.32    2.49    20.1    0.35   0.916
    U         8  28   79   0.903   0.501   0.499   0.871   0.921   0.807       .       .
    L         8  28   79   0.835   0.353   0.462   0.654    3.98      16   0.291    1.09
    U         9   2   79    1.92    1.65   0.575   0.945    1.13   0.818       .       .
    L         9   2   79   0.498   0.276   0.773   0.445    5.77    17.4   0.303    1.05
    U         9   9   79    3.61     6.3    3.23    1.05    2.11    1.22       .       .
    L         9   9   79   0.508   0.306    1.04   0.927    3.65      16   0.331       .
    U         9  20   79    4.38      10    3.84   0.919    3.35    1.38       .       .
    L         9  20   79   0.485   0.612   0.703   0.812    3.76      15    0.31    1.01
    U         9  29   79    3.42     5.1    4.33   0.661    2.71   0.928       .       .
    L         9  29   79   0.198   0.146   0.484    0.68    4.15    9.67   0.169   0.826
    U        10  14   79       .       .       .       .       .       .       .       .
    L        10  14   79       .       .       .       .       .       .       .       .
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PARAMETER=MO

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79   1.91    1.41    2.13    1.73    2.32    1.33       .        .
    L        8    4   79  0.109   0.312   0.184    1.42  0.0763   0.168  0.0757    -0.04
    U        8    6   79   1.36   0.717    1.67    1.46    1.51   0.798       .        .
    L        8    6   79  0.313   0.388       .    1.42   -0.04   0.225   0.219    -0.04
    U        8    7   79   1.02   0.543    1.36   0.919   0.882   0.432       .        .
    L        8    7   79  0.275   0.182       .    1.05   -0.04   0.208   0.208    -0.04
    U        8    8   79      .   0.393       .   0.904       .       .       .        .
    L        8    8   79  0.131   0.119       .    1.08   -0.04   0.141   0.118    -0.04
    U        8   11   79  0.618    0.46   0.795   0.596   0.618   0.338       .        .
    L        8   11   79  0.285   0.213   -0.04    1.11   -0.04   0.247   0.209    -0.04
    U        8   12   79  0.525   0.401   0.602   0.495   0.464   0.305       .        .
    L        8   12   79  0.423   0.242   -0.04   0.888   -0.04   0.272   0.295    -0.04
    U        8   14   79  0.366   0.302   0.575   0.361   0.288   0.199       .        .
    L        8   14   79  -0.04   -0.04   -0.04    0.72   -0.04   0.144  0.0671    -0.04
    U        8   16   79  0.611   0.402   0.701   0.431    0.31   0.282       .        .
    L        8   16   79 0.0532   -0.04   -0.04   0.805   -0.04  0.0995  0.0543    -0.04
    U        8   19   79   0.34    0.24    0.48   0.325   0.297    0.26       .        .
    L        8   19   79 0.0465  0.0738  0.0548    0.84   -0.04   0.153  0.0615    -0.04
    U        8   24   79  0.239   0.101   0.449   0.245   0.178   0.245       .        .
    L        8   24   79  -0.04   -0.04   -0.04   0.796   -0.04   0.112  0.0632    -0.04
    U        8   28   79  0.327   0.309   0.381   0.427   0.343   0.395       .        .
    L        8   28   79  0.164   0.129   0.216   0.857   0.163   0.202   0.296    -0.04
    U        9    2   79   0.33   0.315   0.469   0.442    0.32   0.348       .        .
    L        9    2   79  0.186   0.205   0.169   0.781   0.101   0.232   0.325    -0.04
    U        9    9   79  0.425   0.367    0.54   0.373   0.319   0.349       .        .
    L        9    9   79  0.172   0.149   0.123    0.84   -0.04   0.202   0.296        .
    U        9   20   79  0.316   0.309    0.44    0.26   0.169   0.299       .        .
    L        9   20   79 0.0834  0.0599   0.077   0.749   -0.04  0.0882  0.0989    -0.04
    U        9   29   79  0.235   0.194   0.417   0.201   0.149    0.22       .        .
    L        9   29   79 0.0524  0.0434   -0.04   0.552   -0.04  0.0716   0.113    -0.04
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
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PARAMETER=NI

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7 CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  ------
    U        8    4   79  0.124  0.0842   0.167  0.0865  0.0699   0.107       .       .
    L        8    4   79  0.361   0.175    0.12   0.443  0.0817    1.26   0.118  0.0353
    U        8    6   79   0.08   0.124   0.186  0.0758  0.0454  0.0895       .       .
    L        8    6   79   0.19   0.198       .   0.322  0.0386   0.629   0.147   -0.02
    U        8    7   79 0.0624   0.112   0.103  0.0444  0.0451  0.0647       .       .
    L        8    7   79  0.184   0.141       .   0.253   -0.02   0.595   0.119   -0.02
    U        8    8   79      .  0.0836       .  0.0584       .       .       .       .
    L        8    8   79  0.129   0.113       .   0.248  0.0265   0.532    0.12   -0.02
    U        8   11   79 0.0914    0.12   0.115  0.0813  0.0513   0.082       .       .
    L        8   11   79  0.152   0.135  0.0976   0.255  0.0203   0.552   0.149  0.0601
    U        8   12   79  0.108   0.137   0.113   0.101   0.066   0.121       .       .
    L        8   12   79  0.201   0.165  0.0696   0.231  0.0317   0.476   0.182  0.0663
    U        8   14   79 0.0636  0.0819  0.0586  0.0756  0.0536   0.104       .       .
    L        8   14   79  0.102  0.0882  0.0624   0.208  0.0397   0.425   0.121   -0.02
    U        8   16   79  0.144   0.138   0.144   0.128  0.0567   0.126       .       .
    L        8   16   79  0.122   0.116   0.115   0.224  0.0526   0.417   0.121  0.0413
    U        8   19   79  0.133   0.127   0.116   0.175  0.0693   0.138       .       .
    L        8   19   79  0.138   0.116  0.0923    0.25  0.0709   0.405   0.137  0.0312
    U        8   24   79  0.147   0.101   0.119   0.145  0.0825   0.152       .       .
    L        8   24   79  0.117   0.123   0.109   0.237  0.0731    0.36   0.115   -0.02
    U        8   28   79 0.0995   0.101  0.0905   0.115  0.0769   0.129       .       .
    L        8   28   79  0.106   0.108   0.111   0.231   0.142   0.307   0.119   -0.02
    U        9    2   79 0.0877  0.0933  0.0801   0.093  0.0746    0.11       .       .
    L        9    2   79  0.106   0.111   0.101    0.24   0.152   0.312   0.131  0.0344
    U        9    9   79   0.11   0.121  0.0951  0.0972   0.076   0.104       .       .
    L        9    9   79  0.118   0.103  0.0954   0.221  0.0727   0.272   0.123       .
    U        9   20   79  0.132   0.172   0.147   0.121   0.105   0.161       .       .
    L        9   20   79  0.126   0.129   0.115   0.247   0.115   0.288   0.142   0.049
    U        9   29   79  0.126   0.141   0.117   0.115   0.102   0.146       .       .
    L        9   29   79  0.136   0.127   0.116   0.228   0.117   0.243   0.146  0.0418
    U       10   14   79      .       .       .       .       .       .       .       .
    L       10   14   79      .       .       .       .       .       .       .       .
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PARAMETER=PH

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79   8.22    7.79    8.52    8.04    12.1    9.64       .        .
    L         8   4   79      .     7.8       .    7.83       .    7.55    7.52        .
    U         8   6   79   8.48    7.92    7.77    8.19    11.1    9.21       .        .
    L         8   6   79   7.56    7.61       .    7.96    7.06     7.3    7.58     7.17
    U         8   7   79    8.1    1.27    7.73    8.17      11     7.8       .        .
    L         8   7   79   7.54     7.7       .     7.8    6.14    7.26     7.4      6.7
    U         8   8   79      .       .       .       .       .       .       .        .
    L         8   8   79   7.47    7.65       .       .       .    7.57    7.27        .
    U         8  11   79   7.55    7.69    7.46    7.83    8.95    7.89       .        .
    L         8  11   79   7.34    7.29    7.58    7.66    6.99    7.71    7.52     7.34
    U         8  12   79   7.79    7.81    7.47    7.63    8.83    7.78       .        .
    L         8  12   79   7.42    7.44    7.67    7.67    6.48    7.36    7.45     7.84
    U         8  14   79   7.69    7.91     7.6    7.62    9.19    7.79       .        .
    L         8  14   79   7.46    7.54    7.87    7.79    7.47    7.62    7.46     7.76
    U         8  16   79      .       .    7.86    7.77    9.79    7.69       .        .
    L         8  16   79   7.34    7.45     7.7     7.7    7.18    7.38    7.45     6.85
    U         8  19   79      8    7.43    7.73    7.56    7.59    7.63       .        .
    L         8  19   79   7.21    7.35    7.64    7.66    6.93    7.44     7.4     7.68
    U         8  24   79   7.64    7.76    7.68    7.44     7.4    7.69       .        .
    L         8  24   79   7.52    7.65    7.53    7.55    6.72     7.5    7.13      6.6
    U         8  28   79   7.69    7.64    7.73    7.41    7.75    7.68       .        .
    L         8  28   79   7.55    7.78    7.62     7.9       .    7.78    7.15     6.61
    U         9   2   79   7.84    7.52    7.74    7.73    7.83     7.6       .        .
    L         9   2   79   7.53    7.69    7.68    7.86     7.9    7.35     7.8     6.56
    U         9   9   79   7.63     7.6    7.46    7.51    7.52    7.66       .        .
    L         9   9   79    7.5    7.35    7.46    7.65    7.07    7.39    7.25     6.82
    U         9  20   79   7.87    8.13    8.19    7.47    8.04     7.6       .        .
    L         9  20   79   7.38    7.46    7.67    7.72    7.32    7.31    7.23     6.89
    U         9  29   79   7.38    7.47    7.48    7.26    7.41    7.44       .        .
    L         9  29   79    7.1    7.16    7.27    7.43    6.56    6.98    6.94      6.4
    U        10  14   79   7.27     7.4    7.36     7.3    7.53    7.32       .        .
    L        10  14   79   7.16    7.14    7.21    7.45    5.52    7.05    7.04     6.39
```

```
PARAMETER=K

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79    -40     -40     -40     -40     -40     -40       .        .
    L         8   4   79    180     -40     219     -40    69.6     -40     207     41.7
    U         8   6   79    -40     -40     -40     -40     -40     -40       .        .
    L         8   6   79    -40     -40       .     -40    67.1     -40     154      -40
    U         8   7   79    -40     -40     -40     -40     -40     -40       .        .
    L         8   7   79   46.3     -40       .     -40    55.5     -40     159     47.8
    U         8   8   79      .     -40       .    2340       .       .       .        .
    L         8   8   79    164     -40       .     -40     116     -40     194     64.7
    U         8  11   79    -40     -40     -40     -40     -40     -40       .        .
    L         8  11   79    -40     -40     159     -40    53.8     -40     145      129
    U         8  12   79    -40     -40     -40     -40     -40     -40       .        .
    L         8  12   79    -40     -40     164     -40    46.5     -40    80.9     87.5
    U         8  14   79    -40     -40     -40     -40     -40     -40       .        .
    L         8  14   79    173     -40     142     -40    54.6     -40     210      -40
    U         8  16   79    -40     -40     -40     -40     -40     -40       .        .
    L         8  16   79    148     -40     199     -40    58.8     -40     209      -40
    U         8  19   79    -40     -40     -40     -40     -40     -40       .        .
    L         8  19   79   58.3     -40     202     -40    57.9     -40     206      -40
    U         8  24   79    -40     -40     -40     -40     -40     -40       .        .
    L         8  24   79    114     -40     199     -40    51.2     -40     207      -40
    U         8  28   79   1750    1060    1710    1760    1750    1360       .        .
    L         8  28   79    459     725     227    1250     372     665     289      -40
    U         9   2   79   1680    1110    1680    1560    1700    1290       .        .
    L         9   2   79    447     745     215    1280     348     680     310     49.5
    U         9   9   79   1770    1410    1930    1610    1720    1340       .        .
    L         9   9   79    483     704     189     935     113     589     309        .
    U         9  20   79   1420    1310    1700    1140    1530    1180       .        .
    L         9  20   79    338     480     142     710    91.8     442     197      -40
    U         9  29   79   1190     825    1460     911    1190     972       .        .
    L         9  29   79    439     662     109     600    55.9     626     205      -40
    U        10  14   79      .       .       .       .       .       .       .        .
    L        10  14   79      .       .       .       .       .       .       .        .
```

```
PARAMETER=SE

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8    4   79      .  -0.005       .  -0.005       .  -0.005  -0.005   -0.005
    U        8    6   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8    6   79 -0.005  -0.005       .  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8    7   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8    7   79 -0.005  -0.005       .  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8    8   79      .  -0.005       .       .       .       .       .        .
    L        8    8   79 -0.005  -0.005       .  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   11   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   11   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   12   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   12   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   14   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   14   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   16   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   16   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   19   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   19   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   24   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005       .        .
    L        8   24   79 -0.005  -0.005  -0.005  -0.005  -0.005  -0.005  -0.005   -0.005
    U        8   28   79      .       .       .       .       .       .       .        .
    L        8   28   79      .       .       .       .       .       .       .        .
    U        9    2   79      .       .       .       .       .       .       .        .
    L        9    2   79      .       .       .       .       .       .       .        .
    U        9    9   79      .       .       .       .       .       .       .        .
    L        9    9   79      .       .       .       .       .       .       .        .
    U        9   20   79      .       .       .       .       .       .       .        .
    L        9   20   79      .       .       .       .       .       .       .        .
    U        9   29   79      .       .       .       .       .       .       .        .
    L        9   29   79      .       .       .       .       .       .       .        .
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
```

```
PARAMETER=SI

SAMPLE PT MONTH DAY YEAR  CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7 CELL 12
--------- ----- --- ----  ------  ------  ------  ------  ------  ------  ------  ------
    U         8   4   79    32.7    32.3    19.1    43.7    7.09    39.3       .       .
    L         8   4   79    40.3    24.3      63    24.7    60.1      15    29.2    20.3
    U         8   6   79    34.8    35.1      29    49.1     101    40.8       .       .
    L         8   6   79      16    9.86       .    17.2    13.2    9.41    9.45    10.4
    U         8   7   79    44.5    37.7    31.1    65.3    86.4    54.8       .       .
    L         8   7   79    21.8    20.3       .    30.2    12.4    13.6    13.5    10.2
    U         8   8   79       .    35.8       .    85.3       .       .       .       .
    L         8   8   79      26    24.8       .    33.7    13.5    18.9    16.5    11.5
    U         8  11   79    27.6    26.3    17.3    52.8    81.5    48.1       .       .
    L         8  11   79    20.8    18.1    48.3    30.6      16    17.8    16.6    14.9
    U         8  12   79    20.3    27.8    10.7    33.4      69    35.1       .       .
    L         8  12   79      14    14.2    32.9    18.1    16.1    9.37    10.2    13.5
    U         8  14   79    30.9      51    18.3    54.7    76.5    51.7       .       .
    L         8  14   79      20    18.3    33.2    24.9    15.2    13.4    11.5    11.6
    U         8  16   79    55.5    61.4    28.4    60.4    95.7    67.5       .       .
    L         8  16   79    28.7    30.4    38.2    36.4    17.8    16.5      15    13.3
    U         8  19   79    23.4    20.3    18.1    34.6    87.9    32.8       .       .
    L         8  19   79      32    28.2    45.8    43.8    19.5    21.9    18.7    14.6
    U         8  24   79    34.5      20    26.2    25.1    82.2    39.2       .       .
    L         8  24   79    32.4    33.1    44.6    44.7    22.7    26.7    19.2    16.6
    U         8  28   79    22.7      12    12.5    31.1    66.7    29.4       .       .
    L         8  28   79    29.3    21.4    34.8    36.3    24.9    26.1    15.5    16.4
    U         9   2   79    28.5    17.5    13.2    34.4    58.6    29.2       .       .
    L         9   2   79      25    22.1    38.2    27.9      23    21.7    16.6    15.9
    U         9   9   79    36.3    34.5    21.1    33.8    56.9    36.3       .       .
    L         9   9   79    31.8    27.9    46.3    39.5    24.8    26.8    19.2       .
    U         9  20   79      80    80.2    49.5    56.3     101    65.1       .       .
    L         9  20   79    70.6    71.9    87.6    79.3    51.6      63    45.8    36.1
    U         9  29   79      49    42.7    40.8    43.6    77.8    48.7       .       .
    L         9  29   79    35.5    29.4    69.7    62.1    40.5    27.3    31.4    30.6
    U        10  14   79       .       .       .       .       .       .       .       .
    L        10  14   79       .       .       .       .       .       .       .       .
```

PARAMETER=AG

SAMPLE PT	MONTH	DAY	YEAR	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 6	CELL 7	CELL 12
U	8	4	79	0.0212	0.0142	0.02	.00731	0.0143	0.0143	.	.
L	8	4	79	0.0121	0.0152	0.0177	0.0169	0.0166	0.0279	0.0116	-0.005
U	8	6	79	0.0093	0.0299	0.0267	-0.005	-0.005	0.0188	.	.
L	8	6	79	0.0436	0.0377	.	0.019	-0.005	0.0353	0.036	-0.005
U	8	7	79	-0.005	0.0211	0.0141	.00587	0.011	0.0118	.	.
L	8	7	79	0.0303	0.0196	.	0.0111	.00686	0.0288	0.0225	0.0055
U	8	8	79	.	0.0171	.	0.0375	.	.	.	.
L	8	8	79	0.0195	0.0114	.	0.0136	-0.005	0.0255	0.0141	0.00532
U	8	11	79	0.0172	0.0292	0.0187	.00659	0.0123	0.015	.	.
L	8	11	79	0.0307	0.0285	.00867	0.0116	-0.005	0.0323	0.0244	-0.005
U	8	12	79	0.0246	0.0228	0.0245	0.0184	0.0196	0.0163	.	.
L	8	12	79	0.0469	0.0224	-0.005	0.0152	-0.005	0.0339	0.0332	0.00596
U	8	14	79	-0.005	.00787	-0.005	-0.005	-0.005	-0.005	.	.
L	8	14	79	-0.005	-0.005	-0.005	-0.005	-0.005	0.0328	0.0125	-0.005
U	8	16	79	0.0199	.00829	0.0252	-0.005	-0.005	-0.005	.	.
L	8	16	79	-0.005	-0.005	.00533	-0.005	-0.005	0.0286	.00597	-0.005
U	8	19	79	0.014	0.011	0.0201	-0.005	.00956	0.015	.	.
L	8	19	79	-0.005	.00745	0.0148	-0.005	-0.005	0.0421	.00597	-0.005
U	8	24	79	0.0104	.00597	0.0186	-0.005	.00998	-0.005	.	.
L	8	24	79	-0.005	-0.005	-0.005	-0.005	-0.005	0.0182	0.0203	-0.005
U	8	28	79	0.0246	0.0398	0.0375	0.0383	0.0383	0.0396	.	.
L	8	28	79	0.0359	0.0289	0.0342	0.0205	0.0238	0.0484	0.0572	-0.005
U	9	2	79	0.032	0.0469	0.0424	0.0377	0.0402	0.04	.	.
L	9	2	79	0.0355	0.0301	0.0426	0.0455	0.0336	0.0633	0.068	-0.005
U	9	9	79	0.0426	0.0604	0.0332	0.0295	0.0447	0.0465	.	.
L	9	9	79	0.0426	0.034	0.0222	0.0371	.00661	0.0584	0.0619	.
U	9	20	79	.00709	0.0126	.00549	-0.005	-0.005	-0.005	.	.
L	9	20	79	-0.005	-0.005	-0.005	-0.005	-0.005	0.0108	-0.005	-0.005
U	9	29	79	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	.	.
L	9	29	79	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005
U	10	14	79	.	.	.	.	.	.	.	.
L	10	14	79	.	.	.	.	.	.	.	.

```
PARAMETER=NA

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79   4820    2890    4160    2490    1760    1830       .        .
    L        8    4   79   21.3     440    12.5    3020      -5     621      -5       -5
    U        8    6   79   1880     629    2950    1670    1270     310       .        .
    L        8    6   79    120     345       .    1930      -5     321      -5       -5
    U        8    7   79    962     351    1600     809     463     206       .        .
    L        8    7   79    107     309       .    1510      -5     248      -5       -5
    U        8    8   79      .     352       .    91.3       .       .       .        .
    L        8    8   79    102     277       .    1690      -5     200      -5       -5
    U        8   11   79    833     269    1230     797     448     206       .        .
    L        8   11   79   98.8     301    6.73    1490      -5     196      -5       -5
    U        8   12   79    506     249     515     472     366     172       .        .
    L        8   12   79    110     304      -5     908      -5     249      -5       -5
    U        8   14   79   12.4    34.8      -5    25.2    45.3      49       .        .
    L        8   14   79   47.6    45.1    6.69      -5      -5    49.3      -5       -5
    U        8   16   79     -5    29.9      -5    25.3      48    48.6       .        .
    L        8   16   79   42.9    48.4    5.96      -5      -5    47.7      -5       -5
    U        8   19   79   32.8    49.4      -5    39.1      49    46.3       .        .
    L        8   19   79   48.5    47.7    5.76      -5    6.16    45.4      -5       -5
    U        8   24   79   43.8    41.8    27.4    46.7    49.3    44.2       .        .
    L        8   24   79   46.8    48.9    6.55      -5    7.79    42.5      -5       -5
    U        8   28   79   51.3    30.8    57.4    67.1      50    39.4       .        .
    L        8   28   79   49.1    51.8    11.5     116    27.5    37.2      -5       -5
    U        9    2   79   50.4    30.2    56.3    53.6    49.6    35.9       .        .
    L        9    2   79   36.8    53.3    13.4    84.2    24.7    36.8      -5       -5
    U        9    9   79   54.5    48.9    68.3    60.1    50.6    39.4       .        .
    L        9    9   79   41.7    52.3    13.7     111    13.5    35.9      -5        .
    U        9   20   79    263     249     337     224     242     189       .        .
    L        9   20   79    179     245    55.8     524    68.2     146      -5       -5
    U        9   29   79    190     136     201     181     186     154       .        .
    L        9   29   79    193     182    65.8     419    68.4     156      -5       -5
    U       10   14   79      .       .       .       .       .       .       .        .
    L       10   14   79      .       .       .       .       .       .       .        .
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PARAMETER=504

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CFLL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4   79  26200   16900   32500   16800   11500   19700       .        .
    L        8    4   79      .    3990       .   12800      89    8980    1350        .
    U        8    6   79  13900    7960   26600   13200    9690    5370       .        .
    L        8    6   79   3190    5360       .   11800      90    6060    1600       35
    U        8    7   79   9870    6000   15600    8160    6040    4470       .        .
    L        8    7   79   2830    4320       .    7680     115    5600    1660       27
    U        8    8   79      .       .       .       .       .       .       .        .
    L        8    8   79   2550    4150       .       .       .    5140    1690        .
    U        8   11   79  10600    5520   14000    8960    6380    4880       .        .
    L        8   11   79   2580    3860     336    7940      63    5370    1730      360
    U        8   12   79   8110    5280    7170    6500    6120    4590       .        .
    L        8   12   79   2830    3990     442    7040      84    5480    1770      144
    U        8   14   79   7990    6370    8700    6380    4930    4790       .        .
    L        8   14   79   3080    3960     965    6600     202    5100    1770       30
    U        8   16   79      .       .   11300    6860    5390    6230       .        .
    L        8   16   79   3030    3650    1370    6480     210    4850    1800       65
    U        8   19   79   9070    6030    9700    4940    5390    5570       .        .
    L        8   19   79   3370    4090    1550    6650     340    4390    1810       33
    U        8   24   79   7090    6540    9810    6840    5390    5700       .        .
    L        8   24   79   3160    3850    1780    6330     481    4340    1600       30
    U        8   28   79   5920    4000    5880    6790    5390    6330       .        .
    L        8   28   79   3700    4110    2320    6510    1970    4960    1820       32
    U        9    2   79   5730    4010    5500    5460    5060    4990       .        .
    L        9    2   79   3380    4060    2210    6040    2290    4360    1890      197
    U        9    9   79   6170    5320    7230    6290    5300    5730       .        .
    L        9    9   79   3560    4060    2070    6080     920    4320    2000      116
    U        9   20   79   5740    5860    8240    5450    5520    7090       .        .
    L        9   20   79   3290    3700    1840    6080    1030    4160    2150      108
    U        9   29   79   4980    4150    6810    4340    4600    5360       .        .
    L        9   29   79   3660    3860    2040    5160    1000    4280    2240      100
    U       10   14   79   3060    4000    3750    2330    2800    3130       .        .
    L       10   14   79   3410    3290    2550    3750    3160    4150    2250       41
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PARAMETER=SR

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U        8    4  79    1.03    1.41   0.611     1.7     1.7     1.1       .        .
    L        8    4  79    3.92    2.49     3.4    12.5    2.48    3.05    2.12    0.694
    U        8    6  79    0.98    1.44   0.635    1.08    1.27    1.55       .        .
    L        8    6  79    2.03    1.94       .    8.79   0.392    2.14    1.41    0.175
    U        8    7  79   0.835    1.37   0.509   0.821    1.69    1.07       .        .
    L        8    7  79    1.76    1.81       .    9.66   0.248    2.12    1.44    0.132
    U        8    8  79       .    1.24       .   0.911       .       .       .        .
    L        8    8  79    1.75    1.68       .    9.82   0.248    2.12    1.52    0.154
    U        8   11  79   0.842    1.38   0.473   0.868    1.35    1.04       .        .
    L        8   11  79    1.63    1.59    2.15    9.23   0.244    1.99    1.53    0.408
    U        8   12  79   0.863    1.43   0.465   0.899    1.46    1.23       .        .
    L        8   12  79    1.54    1.62   0.759    7.89   0.246    1.89    1.49    0.224
    U        8   14  79    1.01     1.6   0.562   0.951    1.66    1.23       .        .
    L        8   14  79    1.93    1.78   0.625    9.03   0.349    2.02    1.63    0.134
    U        8   16  79    1.21    1.69    0.54    0.98     1.3    1.21       .        .
    L        8   16  79    1.83    1.73   0.615    9.38   0.368    2.04    1.66    0.173
    U        8   19  79   0.811    1.16   0.512   0.872    1.17    0.92       .        .
    L        8   19  79     1.8    1.69   0.591    9.61   0.381    2.02    1.67    0.152
    U        8   24  79   0.982   0.957   0.565   0.804    1.17   0.939       .        .
    L        8   24  79    1.76    1.68   0.588    9.46   0.421    2.02    1.68    0.154
    U        8   28  79   0.855    1.27   0.538   0.898    1.36   0.861       .        .
    L        8   28  79    2.01    1.89   0.706    9.81    1.66    2.18    1.97    0.176
    U        9    2  79       1    1.45   0.557    0.94    1.42    1.02       .        .
    L        9    2  79    1.92    1.87   0.724    8.84    1.48     2.2    1.99    0.347
    U        9    9  79   0.998    1.38   0.598   0.773    1.38    0.98       .        .
    L        9    9  79    1.96    1.88   0.685    9.77   0.641    2.17    2.09        .
    U        9   20  79   0.943    1.31   0.516   0.743    1.29    0.77       .        .
    L        9   20  79    1.84     1.8   0.583    9.37   0.628    2.01    1.95    0.204
    U        9   29  79    0.98     1.2   0.527   0.891    1.21   0.908       .        .
    L        9   29  79    1.75    1.62   0.556    7.92   0.564     1.8    1.96    0.172
    U       10   14  79       .       .       .       .       .       .       .        .
    L       10   14  79       .       .       .       .       .       .       .        .
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PARAMETER=TDS

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79  44600   29100   61300   28200   22500   28000       .        .
    L         8   4   79      .    6790       .   21700       .   13300    3200        .
    U         8   6   79  24800   14100   43700   23700   18700    9460       .        .
    L         8   6   79   5940    8780       .   20500     258   10100    3560      282
    U         8   7   79  18400   11000   25700   14800   11400    7860       .        .
    L         8   7   79   5330    7290       .   15000     233    9340    3630      219
    U         8   8   79      .       .       .       .       .       .       .        .
    L         8   8   79   5120    7080       .       .       .    8740    3480        .
    U         8  11   79  18600   10100   24600   15800   11700    8470       .        .
    L         8  11   79   5500    7250    1640   15400     225    8780    3300      736
    U         8  12   79  14100    9680   13100   11300   11100    7850       .        .
    L         8  12   79   5800    7490    1560   13600     291    8980    3630      272
    U         8  14   79  13800   11700   15300   11600    9530    8090       .        .
    L         8  14   79   5860    7330    2500   12900     447    8170    3800      201
    U         8  16   79      .       .   20000   12700    9890    8840       .        .
    L         8  16   79   5700    6760    2720   12900     471    7930    3640      172
    U         8  19   79  15700   10700   17200   12600    9940   10100       .        .
    L         8  19   79   6260    7330    2810   13100     636    7900    3620      118
    U         8  24   79  12600   11400   16300   12400   10400   10200       .        .
    L         8  24   79   5920    6980    3290   12300    1080    7770    3480      143
    U         8  28   79  10800    7040   12400   12200   10200   10800       .        .
    L         8  28   79   6750    7430    4350   12300    3610    7810    3670      137
    U         9   2   79  10200    7250    9860   10200    9560    9050       .        .
    L         9   2   79   6040    7310    4160   11500    4060    7730    3630      480
    U         9   9   79  10900    9350   13000   11400    9600    9620       .        .
    L         9   9   79   6320    7150    3960   11400    1670    7110    3820      209
    U         9  20   79  10500   10400   14200    9760    9870   11800       .        .
    L         9  20   79   5960    6660    3550   11300    1820    6990    3870      241
    U         9  29   79   9210    7460   12300    8080    8570    9400       .        .
    L         9  29   79   6490    7010    3950   10100    1930    7400    4430      217
    U        10  14   79   5860    7840    6920    5030    5450    5610       .        .
    L        10  14   79   6240    6330    5120    7130    5410    7080    4170      196
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PARAMETER=TI

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U       8    4   79  0.0265  0.0149  0.0273  0.0177  0.0126  0.0222       .        .
    L       8    4   79  .00926  0.0245  .00777  0.0228  -0.002  0.0257  0.0188   -0.002
    U       8    6   79  0.0125  0.0159  0.0277  0.0133  .00585  0.0145       .        .
    L       8    6   79  0.0284  0.0272       .  0.0218  -0.002  0.0276  0.0257   -0.002
    U       8    7   79  0.0103  0.0186  0.0213  0.0124  .00899  0.0133       .        .
    L       8    7   79  0.0288  0.0217       .  0.0267  .00541  0.0558  0.0245   0.0091
    U       8    8   79       .   0.157       .  .00982       .       .       .        .
    L       8    8   79  0.0894  0.0593       .  0.0196  .00277  0.0237   0.019  0.00267
    U       8   11   79  0.0167  0.0221  0.0182  0.0119  .00845  0.0138       .        .
    L       8   11   79  0.0258  0.0198  .00756  0.0176  .00312  0.0267  0.0215  0.00411
    U       8   12   79  0.0149  0.0208  0.0168  0.0166  0.0119  0.0165       .        .
    L       8   12   79  0.0316  0.0231  .00756   0.018  -0.002  0.0247  0.0263  0.00346
    U       8   14   79  .00637    0.01  0.0112  .00234  -0.002  .00594       .        .
    L       8   14   79   0.014  .00937  .00262  .00732  -0.002  0.0158  0.0127   -0.002
    U       8   16   79  0.0155  0.0113  0.0147  .00393  -0.002  .00965       .        .
    L       8   16   79  0.0159  .00965  0.0081  0.0093  -0.002  0.0164  0.0132   -0.002
    U       8   19   79  0.0134  0.0107  0.0141  0.0125  .00259   0.016       .        .
    L       8   19   79  0.0134  0.0123   0.011  0.0105  -0.002  0.0186  0.0156   -0.002
    U       8   24   79  0.0122  .00753  0.0128  0.0136  .00711  0.0159       .        .
    L       8   24   79  0.0114  .00912  0.0113  0.0111  -0.002  0.0189  0.0149   -0.002
    U       8   28   79  0.0222  0.0181  0.0157  0.0223  0.0155  0.0247       .        .
    L       8   28   79  0.0241  0.0213  0.0246  0.0178  0.0114  0.0254  0.0278   -0.002
    U       9    2   79   0.013  0.0161  0.0131  0.0183  0.0114  0.0219       .        .
    L       9    2   79   0.023  0.0204  0.0219   0.021  0.0108  0.0236  0.0287   -0.002
    U       9    9   79  0.0187  0.0152  0.0162  0.0152  .00923  0.0199       .        .
    L       9    9   79  0.0195   0.017   0.015  0.0177  -0.002  0.0198  0.0277        .
    U       9   20   79  0.0303  0.0304  0.0248  0.0212  0.0113  0.0328       .        .
    L       9   20   79  0.0318  0.0206  0.0243  0.0243  -0.002  0.0281  0.0338   -0.002
    U       9   29   79  0.0203  0.0171  0.0117  0.0104  .00513  0.0191       .        .
    L       9   29   79  0.0211  0.0188  0.0152  0.0104  -0.002  0.0186  0.0328   -0.002
    U      10   14   79       .       .       .       .       .       .       .        .
    L      10   14   79       .       .       .       .       .       .       .        .
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PARAMETER=TOC

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79      .      32      32      55      24      23       .        .
    L         8   4   79      .      21       .      37       .     8.2      39        .
    U         8   6   79     31      23      27      32      31      14       .        .
    L         8   6   79     17     8.3       .      20       9     4.5     7.5      3.5
    U         8   7   79      .       .      18      18      17      11       .        .
    L         8   7   79     15      11       .      22     4.6       6     8.5      4.5
    U         8   8   79      .       .       .       .       .       .       .        .
    L         8   8   79      .       .       .       .       .       .       .        .
    U         8  11   79     19      15      23      21      15      12       .        .
    L         8  11   79     14      10       .      20     7.9     7.2     8.7      6.9
    U         8  12   79     10      12     7.6      14     9.9      11       .        .
    L         8  12   79     12       7      19      17     7.9     2.6     5.5      5.2
    U         8  14   79     13       .     8.1      18     7.3      14       .        .
    L         8  14   79    9.5     6.4      14      12     4.2     3.7       6      3.6
    U         8  16   79      .       .      15      38      14       .       .        .
    L         8  16   79     14      12      16      20     5.9     4.8     6.4      5.8
    U         8  19   79     13     9.8     9.2      23      20      15       .        .
    L         8  19   79     15     8.7      18      23     6.4     5.9     8.7      7.5
    U         8  24   79     15      13      12      13      12      16       .        .
    L         8  24   79     14      10      16      18     7.4     6.3       8      9.3
    U         8  28   79     15     5.1     3.3      14     7.8      11       .        .
    L         8  28   79     14     6.1      14      14      10       6       6      7.6
    U         9   2   79    9.5     7.1     4.8      17      11      12       .        .
    L         9   2   79     10     6.1      12     7.7     7.6     5.6     7.4      7.3
    U         9   9   79     16      15      14      18      11      12       .        .
    L         9   9   79     14     8.2      17      10     6.5     5.1     6.7      8.4
    U         9  20   79      .       .      24      20      22      22       .        .
    L         9  20   79     26      21      25      16      16     9.5      13       17
    U         9  29   79    9.8     9.6      14     8.9     9.1      14       .        .
    L         9  29   79    7.8     4.8      15      13     7.6     2.8     9.4       12
    U        10  14   79    6.8      13     7.2     8.6     3.8     6.5       .        .
    L        10  14   79    5.1     8.2     9.3     5.7     3.2     2.1     6.6        9
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PARAMETER=V

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U         8   4   79  0.759   0.378    0.96   0.577   0.035   0.658       .        .
    L         8   4   79  0.389   0.567   0.303   0.593  0.0276   0.699   0.214    0.139
    U         8   6   79  0.441   0.277    0.88   0.469   0.028    0.18       .        .
    L         8   6   79  0.334   0.377       .   0.477   -0.01   0.594    0.25   0.0168
    U         8   7   79  0.274   0.285   0.593   0.218  0.0236   0.118       .        .
    L         8   7   79  0.326   0.334       .   0.384   -0.01   0.592   0.253    -0.01
    U         8   8   79      .   0.278       .   0.378       .       .       .        .
    L         8   8   79    0.3   0.313       .   0.393   0.022   0.559   0.243   0.0153
    U         8  11   79  0.236   0.271   0.468   0.326  0.0342   0.214       .        .
    L         8  11   79  0.319   0.318  0.0909   0.356   -0.01   0.586   0.261   0.0646
    U         8  12   79  0.168   0.213   0.267   0.167  0.0375   0.165       .        .
    L         8  12   79  0.345   0.332   0.148   0.301   -0.01    0.57   0.279   0.0286
    U         8  14   79  0.261   0.246   0.454   0.213   0.022   0.208       .        .
    L         8  14   79  0.321   0.313   0.241   0.304  0.0295   0.564   0.259   0.0159
    U         8  16   79  0.533   0.302   0.582   0.294  0.0365   0.282       .        .
    L         8  16   79  0.314   0.303   0.274   0.332   0.027   0.555    0.26    0.015
    U         8  19   79   0.39   0.453   0.476   0.411  0.0562   0.508       .        .
    L         8  19   79  0.334   0.324   0.295    0.35  0.0339   0.566   0.264    -0.01
    U         8  24   79  0.393   0.264   0.499   0.454  0.0773   0.497       .        .
    L         8  24   79  0.309   0.311   0.312   0.337  0.0416   0.551   0.263    -0.01
    U         8  28   79   0.31   0.314   0.234    0.56   0.111   0.674       .        .
    L         8  28   79  0.422   0.391   0.451   0.408   0.316   0.609   0.348    -0.01
    U         9   2   79  0.283    0.25   0.252    0.42   0.087   0.482       .        .
    L         9   2   79    0.4    0.39    0.44    0.45   0.359   0.632   0.358   0.0478
    U         9   9   79  0.457   0.406   0.527   0.557   0.175   0.569       .        .
    L         9   9   79  0.411   0.393   0.417   0.451   0.138   0.626   0.372        .
    U         9  20   79  0.942   0.923    1.21    1.05   0.263    1.42       .        .
    L         9  20   79  0.757   0.754   0.759   0.863   0.295    1.18    0.69    0.051
    U         9  29   79  0.777   0.775    1.04   0.776     0.3    1.13       .        .
    L         9  29   79  0.766   0.743   0.741   0.766   0.263    1.01     0.7   0.0261
    U        10  14   79      .       .       .       .       .       .       .        .
    L        10  14   79      .       .       .       .       .       .       .        .
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PARAMETER=ZN

SAMPLE PT MONTH DAY YEAR CELL 1  CELL 2  CELL 3  CELL 4  CELL 5  CELL 6  CELL 7  CELL 12
--------- ----- --- ---- ------  ------  ------  ------  ------  ------  ------  -------
    U       8     4  79   0.313  0.0201    0.45  0.0473  -0.002   0.131       .        .
    L       8     4  79     0.5    0.13   0.331   0.156   0.355   0.825   0.117     0.26
    U       8     6  79  0.0568   0.032   0.269  0.0276  -0.002  -0.002       .        .
    L       8     6  79   0.068  0.0693       .  0.0758  0.0351   0.326  0.0339   0.0403
    U       8     7  79   0.005  0.0253  0.0895  -0.002  -0.002  -0.002       .        .
    L       8     7  79  0.0661  0.0571       .  0.0716  0.0238   0.341  0.0462    0.045
    U       8     8  79       .   0.055       .  0.0587       .       .       .        .
    L       8     8  79   0.043  0.0455       .  0.0652  0.0404   0.277    0.04   0.0637
    U       8    11  79  0.0304  0.0536  0.0464  0.0115  -0.002  -0.002       .        .
    L       8    11  79  0.0432  0.0482  0.0801  0.0571  0.0344   0.293   0.078   0.0678
    U       8    12  79  0.0263  0.0565  0.0223  -0.002  -0.002  -0.002       .        .
    L       8    12  79  0.0447  0.0516  0.0285  0.0427  0.0235   0.228   0.045    0.045
    U       8    14  79  0.0205     0.1  0.0472  .00267  -0.002  -0.002       .        .
    L       8    14  79  0.0254  0.0324  0.0282  0.0387  0.0241   0.233   0.025   0.0257
    U       8    16  79  0.0868   0.161   0.098   0.014  -0.002  .00457       .        .
    L       8    16  79  0.0235  0.0378  0.0226  0.0476  0.0275    0.24  0.0322   0.0271
    U       8    19  79  0.0425   0.122  0.0554  0.0494  -0.002  0.0533       .        .
    L       8    19  79  0.0281  0.0368   0.021  0.0486  0.0444   0.239  0.0405   0.0328
    U       8    24  79   0.043  0.0531  0.0833  0.0679  -0.002  0.0413       .        .
    L       8    24  79  0.0236  0.0366   0.028  0.0589  0.0467   0.209   0.111   0.0301
    U       8    28  79  0.0612   0.059  0.0312  0.0952  0.0148  0.0722       .        .
    L       8    28  79  0.0519  0.0606  0.0569  0.0604  0.0962   0.183  0.0732   0.0722
    U       9     2  79   0.032  0.0811  0.0297   0.083  0.0166  0.0426       .        .
    L       9     2  79  0.0575  0.0542  0.0566  0.0736  0.0978   0.197  0.0955   0.0713
    U       9     9  79  0.0631    0.17  0.0647  0.0963  0.0189  0.0567       .        .
    L       9     9  79  0.0685   0.057  0.0636   0.115  0.0857   0.181  0.0948        .
    U       9    20  79  0.0619   0.229  0.0706  0.0603  0.0113  0.0782       .        .
    L       9    20  79   0.061  0.0555  0.0438   0.127  0.0865   0.155   0.092   0.0615
    U       9    29  79  0.0448   0.112  0.0502  0.0468  0.0169  0.0405       .        .
    L       9    29  79  0.0381  0.0345   0.035  0.0708  0.0723  0.0972   0.075   0.0428
    U      10    14  79       .       .       .       .       .       .       .        .
    L      10    14  79       .       .       .       .       .       .       .        .
```

APPENDIX II

PROCEDURAL DETAILS FOR METHODS OF INVESTIGATION

METHODS USED FOR X-RAY DIFFRACTION ANALYSES

X-ray diffraction has been applied to identify qualitatively the various crystalline components present in the FBC waste and disposal media. A powder sample composed of an aggregate of a large number of tiny crystallites is prepared so that the sample is oriented in random order. X-ray radiation emitted from a copper K_α source is directed upon the randomly oriented flat sample. A complete diffraction scan from 10° to 90° is recorded for each specimen. As the specimen is irradiated by the incident x-radiation, each set of crystal planes in the various crystallites reflects the diffracted beam which is then detected by a scintillation counter and recorded on a chart paper as a series of X-ray intensity peaks.

The patterns are taken using a Siemens X-ray powder diffractometer for this investigation. The scan is recorded at a rate of 1° per minute. Interplanar d-spacings are calculated from the X-ray intensity peaks using Bragg's Law.

In general, only species present in major proportions (at least 5 to 10 percent) can be identified by X-ray diffraction. The limits of detectability are strongly dependent on the intrinsic intensity of the diffraction pattern of a given species and the amount and type of other crystalline species present.

The powder diffraction technique employed for the current study yields qualitative rather than quantitative information, but some semiquantitative information is available. For a given crystalline species, the intensity of its pattern will increase with an increasing amount of the species in the sample. However, if two species are present, the one with the more intense pattern is not necessarily present in the higher proportion.

The indexed d-spacings for various components in the PFBC wastes have been identified by two methods. For discrete powder patterns, a hand search of the Hanawalt Index Powder Diffraction File has been performed. A computerized data handling system has also been used to identify and evaluate candidate crystalline species which might produce minor diffraction intensities. The system used is the Powder Diffraction Search Match (PDSM) component of the NIH/EPA Chemical Information System. The crystalline phases found in the wastes will be used in the final analysis of the leaching phenomena to determine which phases control the leachate concentration of key species.

METHODS USED IN ELECTRON MICROSCOPE ANALYSES

The scanning electron microscope (SEM) used in this investigation allows magnifications of the microstructure up to 50,000 times. In the SEM, electron lenses demagnify the source image and produce a focused spot (or probe) on the sample. This spot scans the area under examination in the same manner as a television camera, and the reflected electrons are picked up by a suitable detector. After the signal is amplified, it can be displayed on a cathode-ray tube or projected onto Polaroid film for a permanent record of the surface microstructure.

Small pieces of the waste are mounted on carbon discs so that representative surfaces are available for examination. An adhesive-containing graphite is used to secure the samples to the base. The mounted samples are placed in a vacuum chamber and coated with gold.

For this investigation, an Etec Omniscan scanning electron microscope is used with a Princeton Gamma Tech Model 1000 energy dispersive X-ray fluorescence spectrometer. Standard conditions for electron microprobe analysis are used as follows:

- voltage: 20 kV,

- working distance: 25 mm,
- tilt: 30 degrees, and
- horizontal distance from center of column to detector: 20 mn.

Scanning electron micrographs have been produced under two different instrumental conditions yielding micrographs first showing low magnification (1000 X) of general surface microstructure, and then at higher magnification (5000 X) to illustrate detailed surface analysis of a specific area.

Electron microprobe analyses at two depths are also being performed on the wastes in representative sample areas. This analysis provides data from which surface specific elements can be identified.

DETAILS OF SAMPLE AND APPARATUS PREPARATION

As noted in the text, several steps are required before and after samples are generated in the multi-step laboratory leachate protocol.

Preparation of Solids

Depending on the types of solids to be used in the leaching studies, it is necessary to perform some type of initial preparation such as drying, grinding, and bulk mixing in order to obtain a representative sample which can be reproduced from batch to batch. The wastes and media are initially dried at a low temperature (~50°C). This temperature was selected in order to avoid loss of waters of hydration which in turn might alter the leachability of the material. The attenuation media are coned and quartered, and any large chunks or clods are broken down to approximately 4 mesh before drying. After drying, the media are ground to approximately 100 mesh. No attempt is made to size the particles since the intention is to gain a representative sample, not to increase the surface area of the material.

Preparation of Apparatus

The mixing apparatus has a head with an adjustable angle of incline and a variable speed control. For the purpose of this study, the incline of the head is adjusted to an angle of approximately 70° to the horizontal. This results in an end-over-end action of the leachate/waste within the container. The speed of rotation is set at approximately 6 rpm.

Preparation of Leachate Containers

The containers selected for the leaching protocol are 250 ml polypropylene centrifuge containers manufactured to fit the centrifuge used for the leachate-solid phase separation. The containers are cleaned with dilute (1:5) nitric acid and rinsed with deionized water to remove any contaminants prior to use. Sufficient containers are provided to minimize reuse.

Separation of Leachate from Solids After Leaching

The solid/liquid phases of the samples are separated by centrifugation in a high-speed centrifuge (IEBC-20A) at 2,500 rpm for a period of twenty minutes. The leachate is then carefully decanted off the solids and the appropriate phase is either carried forward to another shake test or prepared for chemical analysis.

Sample Preservation

Following solid/liquid phase separation, one or both of the phases may require preparation or preservation for chemical analysis. The liquid phase (leachate) is divided into four aliquots and each aliquot is preserved by an appropriate technique for the analyses to be performed. Figure II-1 indicates the sample divisions and preservation techniques used.

The solid phase is prepared for analysis by drying overnight at 50°C followed by grinding with a mortar and pestle. No additional preservation is necessary.

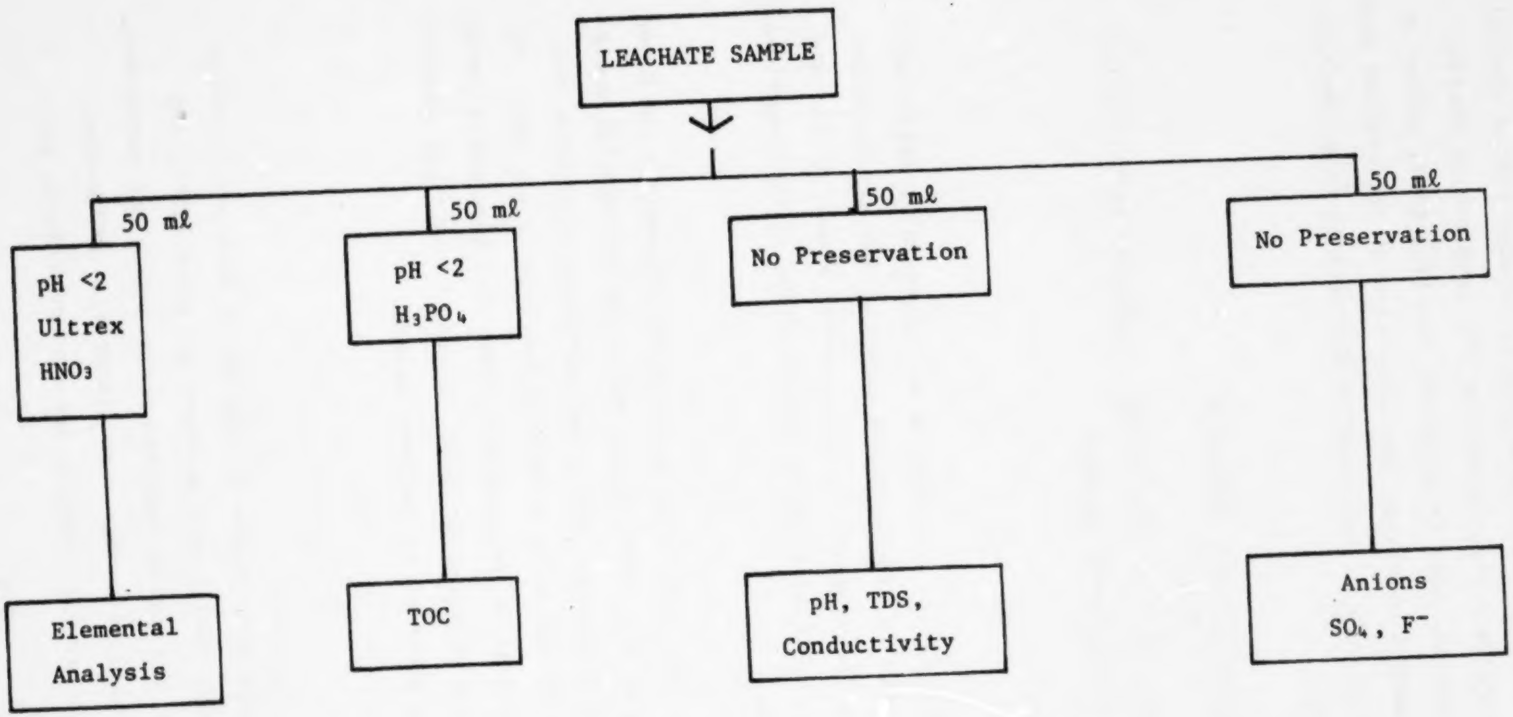
LEACHATE SAMPLE
50 mℓ
pH <2
Ultrex
HNO₃
50 mℓ
pH <2
H₃PO₄
50 mℓ
No Preservation
50 mℓ
No Preservation
Elemental
Analysis
TOC
pH, TDS,
Conductivity
Anions
SO₄, F⁻

Figure II-1. Preservation Protocol for Leaching Samples

Each leachate or solid prepared for analysis is labeled with a special code of at least seven characters which indicates the sample type (waste, leachate, or attenuation media), step in protocol, leaching time, number of repeats of step, identification of waste, identification of attenuation medium, and duplicate samples. This code is explained in Appendix II under Details of Data Analysis Procedures.

DETAILS OF FIELD CELL CONSTRUCTION AND OPERATION

The field cells are erected in a ring around a seventh, larger central cylinder, which serves as an equipment shelter.

Construction

Initially, a prototype cell was constructed and operated at Radian's Austin facility. This was done to ensure smooth construction and operation procedures. While this exercise revealed no major system flaws, it did aid significantly in optimizing both construction and operation of the functional cells, thus saving field time.

The 17 functional cells (plus one spare cell) were emplaced at the Crown field site. The three rings of six field cells, each with its central equipment shell, are set on end in a trench. Connector pipes are installed, and local soil is backfilled around the cells to within one foot of the top. The bottom of each cell is sealed with an impermeable liner, and succeeding layers of disposal media and waste are emplaced by hand. Porous ceramic cup samplers and soil moisture sensors are emplaced in the sand layers.

Filling Procedures

Disposal media were brought from onsite stockpiles in bulk and shoveled into each cell from the surface. Media were emplaced in level lifts, but not compacted. In the case of the coarse textured media (shale and sandstone), particles larger than approximately 4 inches were discarded. FBC wastes, which were received as separate streams (beddraw and cyclone catch), were mixed in a rotating drum cement mixer in the same ratio as the original production. Bulk densities of the individual waste streams were determined on site, and the actual mixing was done by volume. Small amounts of deionized water were added until the mixed waste was just sensibly moist.

Beyond that compaction provided by dropping material from the land surface, neither the disposal media nore the FBC wastes were compacted during the filling process. It is deemed more important to provide unrestricted downward flow of leachate than to attempt restoration of in-situ permeability. There is an implied trade-off between modeling actual water flow rates and providing sufficient flow to observe leachate behavior over time.

Special Techniques

Two aspects of cell design and construction are worthy of special mention as useful in any large soil column experiments. These are a system of internal baffles and the soil moisture sampling arrays.

Circumferential baffles are cemented to the walls to prevent infiltrating rainfall or percolating leachate from channeling along the cell walls. Loss of mass flow through the column contents due to short circuiting along the walls is a common problem. A series of small baffles on the wall should solve this channeling problem. The baffles are assembled from 4-inch-wide strips of 30 mil chlorinated polyethylene pond liner, folded in half, lengthwise. One half of the strip is cemented to the wall of the cylinder, the other half is laid out to form a horizontal baffle. Six baffles are emplaced in each cell, at the positions shown on Figure 8. Preliminary observations indicate that significant short circuiting is not occurring, as discussed in subsequent sections. A limitation to the technique is that the cylinder must be large enough to allow access for installation. It is also a labor-intensive procedure requiring nearly a man-day per cell for installing the baffles and hand painting the exposed concrete with coal tar epoxy. If the baffles had not been installed, the supplier would have coated the pipe much more efficiently as part of the manufacturing process.

The porous cup sample array is devised to give an integrated sample on the whole cross section of the cell. It will also produce water at a tolerable rate to minimize sample time. Eight porous ceramic cups are fitted with nylon fittings cemented in place with epoxy adhesive. They are then connected with a manifold "harness" of Tygon® tubing and nylon "T" connectors to a vacuum flask in the equipment shell as shown on Figure II-2.

The final "T" connection is made inside the central equipment shell. Thus, if a portion of the apparatus should fail, leachate may still be collected with the remaining portion. Also, a number of large porous ceramic cups, originally intended for botton drains, were available. These were emplaced near the center of the upper array as spare sample collection devices.

Operation and Sampling

Cells 1 to 7 and cell 12 were placed in operation on 1 August 1979. An initial irrigation of 254 mm of deionized water was applied to bring cell contents to field moisture capacity and initiate sampling. The schedule for the initial irrigation is shown on Table II-1. The first leachate samples were collected on 4 August 1979. Since then, the cells have been exposed to natural precipitation only. The only other departure from real-world conditions is that runoff, which would be maximized in an actual disposal site, is prevented. This allows infiltration into the cell to correspond with rainfall, a measurable phenomena. It also provides a worst plausible case of rainfall ponding on a landfill site.

TABLE II-1. INITIAL IRRIGATION SCHEDULES

Date	Depth (mm)	Volume (liters)
8/1/79	152	177.9
8/2/79	51	59.3
8/4/79	51	59.3

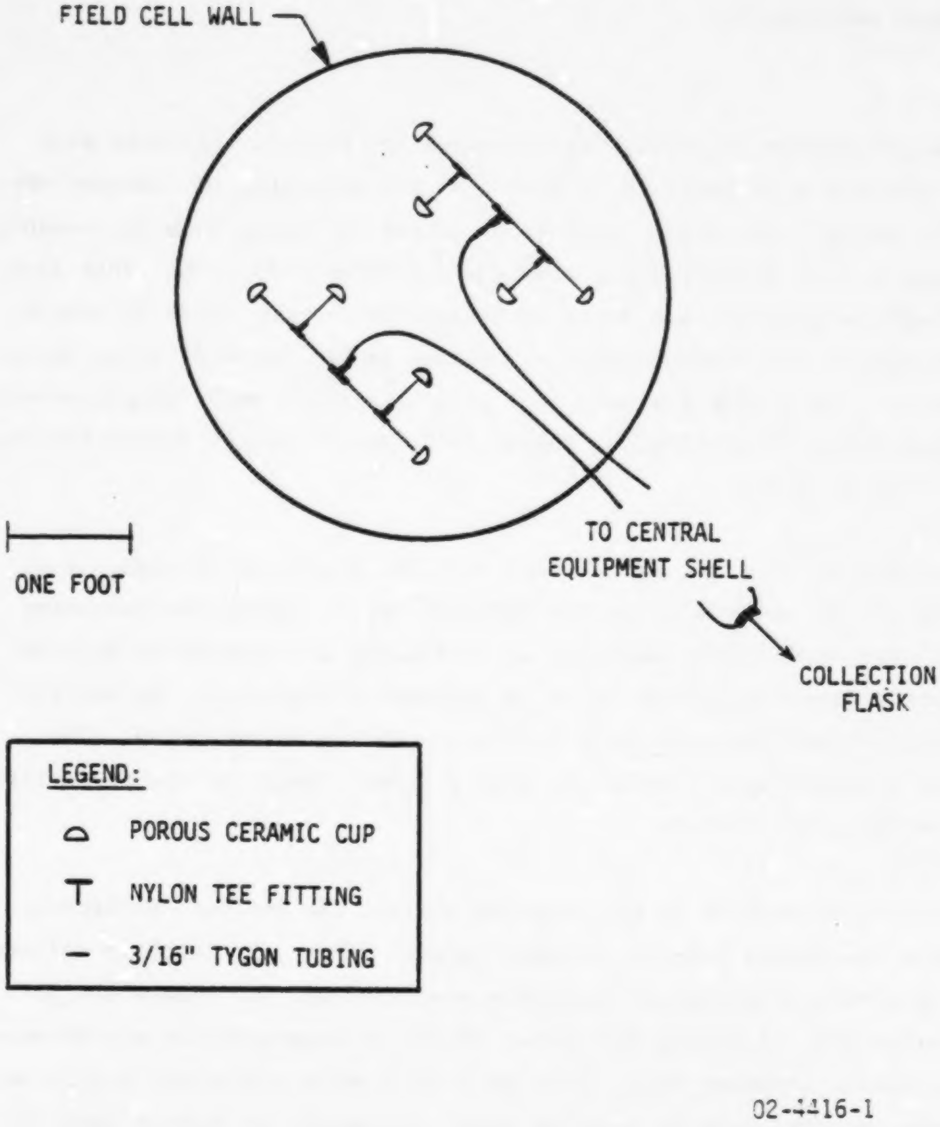
FIELD CELL WALL
TO CENTRAL EQUIPMENT SHELL
ONE FOOT
COLLECTION FLASK
LEGEND:
⌓ POROUS CERAMIC CUP
T NYLON TEE FITTING
— 3/16" TYGON TUBING
02-4416-1

Figure II-2. Detail of Porous Cup Sampler Array

After the first week of sampling, all Crown onsite activities were turned over to two experienced local researchers who are responsible for sample collection, preservation and shipping, field measurements and observations, and equipment maintenance.

Schedule--

Sample collection frequency has an increasing period, beginning with the first appearance of leachate, inasmuch as the phenomena of interest are expected to change less rapidly with time. Expected sample days are roughly equally spaced along a logarithmic time scale (Table II-2). The table also shows "actual" sample days and dates of collection for the first 17 events. The latter part of the schedule may be modified in the light of early analytical results. The target for each cell will be a total of 24 sample events for the Crown cells "producing" by August 1979, and 20 sample events for those cells constructed later.

The departure of actual sample days from the scheduled or expected day is a result of the variability of the rainfall input. After the operating cells were brought to field capacity, no additional irrigation was applied. Leachate moves down through the cells in response to rainfall. In the absence of significant rainfall, very little sample can be extracted. The variability in the sample schedule is thus a direct result of the variability in the appearance of leachate.

For the first portion of the sampling period, the leachate collection systems were maintained under a constant vacuum. Thus, the leachate collected represented a time-proportional composite sample of all flow since the preceeding collection. A time-proportional sample is composited by withdrawing water at a small, constant rate. Samples 1 to 12 were collected in this manner. As the interval between sampling event increases, it becomes less desirable to attempt continuous sampling. Vacuum flasks are filled to capacity within a few days and begin to overflow. Subsequent leachate sample withdrawals are incompletely mixed with the static flask contents; excess sample flows to waste in one of the bottom drain drums. Installing larger vacuum flasks merely postpones the onset of this difficulty. Continuous sample with-

TABLE II-2. SAMPLE SCHEDULE FOR FIELD CELLS 1 TO 7 AND 12

Sample Number	Scheduled Day	Actual Day	Date
1	1	0	4 August 1979
2	2	2	6 August 1979
3	3	3	7 August 1979
4	4	4	8 August 1979
5	5	7	11 August 1979
6	6	8	12 August 1979
7	8	10	14 August 1979
8	10	12	16 August 1979
9	13	15	19 August 1979
10	16	20	24 August 1979
11	20	24	28 August 1979
12	25	29	2 September 1979
13	32	36	9 September 1979
14	40	47	20 September 1979
15	50	56	29 September 1979
16	63	71	14 October 1979
17	79	89	1 November 1979
18	100		
19	126		
20	158		
21	200		
22	251		
23	316		
24	398		
25	501		

drawals from the upper sampling array biases cell operation by removing a significant fraction of the infiltrating leachate before it interacts with the underlying disposal media. More importantly, flow through the field cells varies with time, both in quantity and quality. A time-proportional composite sample of a varying flow system is not representative, and, hence, not desirable.

Accordingly, the sample collection scheme was modified for sample 13 and subsequent samples. On an assigned "sample day," the operator turns on the sampling system. He then awaits a precipitation event, returns the day following such an event, collects a sample, and turns off the system. This procedure provides a sample representative of conditions at the time, rather than an imperfect composite of previous conditions.

Sampling Procedure--

The sampling procedure is composed of the following steps:

- Each drum is pumped out; the quantity of throughput and the pH and electrical conductivity of the contents of each drum are measured and recorded.
- The racks containing the vacuum flasks are removed for breakdown; the volume in each vacuum flask is recorded; and the contents of the two flasks servicing a single sample point are composited.
- The pH and electrical conductivity of each sample are measured, and the sample is split and preserved according to a written protocol, as shown on Figure II-3.
- Vacuum is reapplied to the drums, the vacuum flask racks are reassembled, but not connected to vacuum, and the site secured.

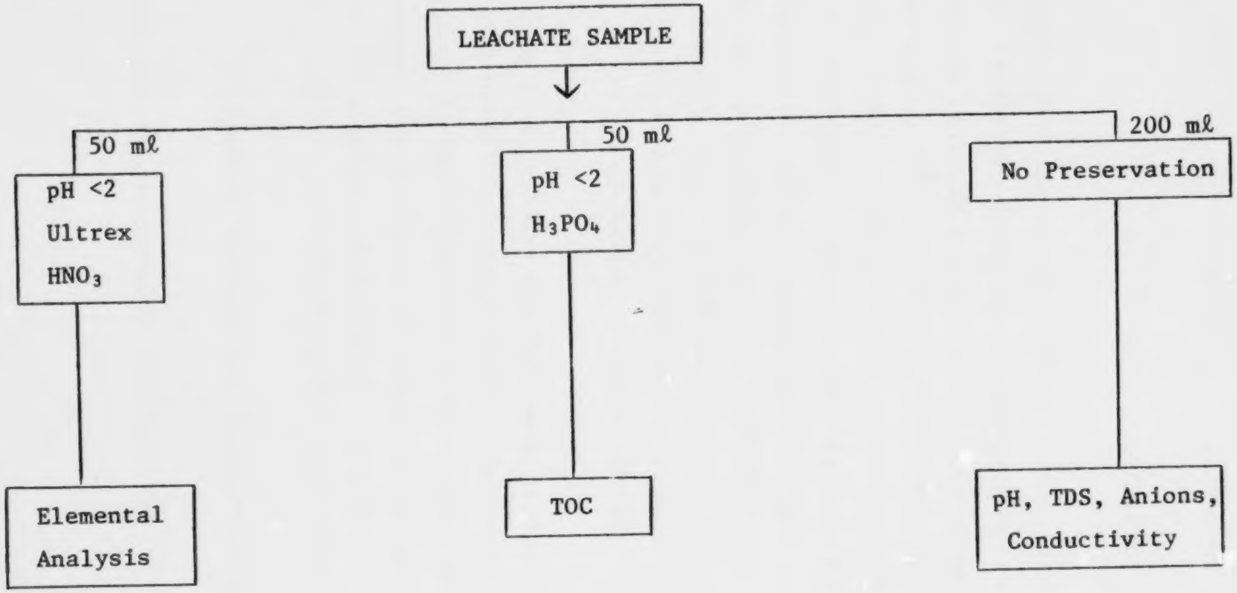
LEACHATE SAMPLE
50 mℓ
pH <2
Ultrex
HNO₃
Elemental
Analysis
50 mℓ
pH <2
H₃PO₄
TOC
200 mℓ
No Preservation
pH, TDS, Anions,
Conductivity

Figure II-3. Preservation Protocol for Field Cell Leachate Samples

- At monthly intervals, the chart and batteries for the recording rain gage are changed.
- Samples are packed in ice chests and shipped to Radian's Austin laboratories for analysis.

ICPES ACCURACY AND PRECISION DETERMINATION

Most of the chemical analytical work for this program has been performed with an inductively coupled argon plasma emission spectroscopy (ICPES) technique. Initial tests have been performed with an Applied Research Laboratories Model 137. Table II-3 presents the results of analysis of both spiked and unspiked deionized water and a seven-day waste leachate sample. Thirty analyses were performed on each of the four samples. The precision, as defined by comparison of the standard deviations and means of spiked samples, is exceptionally good. The recovery of spiked elements indicates the accuracy of the method is exceptionally good, also. In this instance, spikes of boron, calcium, potassium, and strontium for the leachate sample were too small relative to the total concentration to allow confident recovery evaluation.

The analysis of samples consists of measuring the emitted light at a specific wavelength inherent for each element with a photomultiplier tube. The voltage from each tube is then compared to a standard calibration curve correlating emission at four concentration levels to determine the concentration of an element present in the sample. Calibration standards are produced each day to insure proper calibration and instrument operation.

QUALITY ASSURANCE AND QUALITY CONTROL METHODS FOR CHEMICAL ANALYSIS

The elements of quality control for chemical analysis include the following:

- calibration of instruments,

TABLE II-3. ANALYSIS OF SYNTHETIC AND LAB STUDY LEACHATE SAMPLES*

Element	DI Water Sample				Leachate Sample L1701			
	Sample**	Spike**	Spike + Sample**	Spike Recovery (%)	L1701**	Spike	Spike + Sample**	Spike Recovery (%)
Ag	< 0.005	---	< 0.005	---	0.040± 0.03	---	0.042± 0.004	---
Al	< 0.060	0.50	0.52 ± 0.01	104	0.84 ± 0.04	0.50	1.40 ± 0.11	112
B	< 0.004	1.00	0.95 ± 0.05	95	7.50 ± 0.13	1.00	8.30 ± 0.40	80***
Ba	0.004 ± 0.001	0.50	0.48 ± 0.02	96	0.35 ± 0.01	0.50	0.80 ± 0.02	90
Ca	0.010 ± 0.005	5.0	4.80 ± 0.05	96	1470 ± 17	5.0	1470 ± 19	---***
Cd	< 0.005	0.50	0.47 ± 0.01	94	< 0.005	0.50	0.52 ± 0.01	104
Co	< 0.15	0.50	0.50 ± 0.01	100	1.4 ± 0.08	0.50	1.97 ± 0.11	114
Cr	< 0.005	0.50	0.48 ± 0.02	96	0.07 ± 0.02	0.50	0.53 ± 0.04	92
Cu	< 0.005	0.50	0.46 ± 0.02	92	0.01 ± 0.005	0.50	0.49 ± 0.05	96
Fe	< 0.005	0.50	0.49 ± 0.03	98	0.045 ± 0.010	0.50	0.490 ± 0.005	89
K	< 40.	5.0	< 40	---	700 ± 10	5.0	760 ± 43	---***
Mg	0.002 ± 0.001	0.50	0.49 ± 0.003	98	0.022 ± 0.002	0.50	0.464 ± 0.009	88
Mn	< 0.001	0.50	0.46 ± 0.03	92	0.002 ± 0.001	0.50	0.49 ± 0.03	98
Ni	< 0.020	0.50	0.48 ± 0.01	96	0.15 ± 0.05	0.50	0.68 ± 0.015	106
Si	< 0.020	0.25	0.26 ± 0.008	104	0.60 ± 0.10	0.50	1.08 ± 0.04	96
Sr	< 0.001	0.50	0.49 ± 0.02	98	2.85 ± 0.10	0.25	3.05 ± 0.04	80
Ti	< 0.001	0.25	0.26 ± 0.005	104	0.056 ± 0.010	0.25	0.290 ± 0.008	94
V	< 0.010	0.25	0.24 ± 0.01	96	0.11 ± 0.008	0.25	0.34 ± 0.009	92
Zn	< 0.002	0.50	0.47 ± 0.01	94	0.007 ± 0.003	0.50	0.48 ± 0.01	95

*All concentrations in μg/ml

**Mean ± standard deviation for 30 determinations.

***Spikes were too small in comparison with sample Concentration to accurately define recovery.

- analysis of spiked synthetic and leachate samples,
- analysis of standard samples of known concentration to validate measurements, and
- replicate measurement in the laboratory.

Calibration of Instruments--

The standards used for the ICPES and ion chromatography (IC) instruments are obtained commercially and are diluted by the instrument operator to the desired concentration. Calibration of the instruments is performed on each day on which analyses are made. Multipoint calibrations are used. A deionized water blank and standards at three non-zero concentrations are used to cover the range of concentration of interest. The ICPES automatically performs a regression analyses to determine the calibration curve. Calibration (linear regression) for the IC instrument is performed manually. Table II-4 and Figure II-4 present calibration examples.

Spiked Samples--

The use of spikes (or addition of known amounts of component) was initially employed to define the acceptability of the ICPES methodology. Table II-3 presents the spiking results and recovery of spiked components in the analysis for both deionized water and a laboratory leachate sample. The initial samples and spiked samples were analyzed 30 times to provide statistical information.

Standard Samples--

Analysis of known standard samples has been performed to check for stability of the ICPES instrument. Table II-5 presents the concentration of a standard solution that was analyzed after each ten samples. Lower-level standards are analyzed to define accuracy in the sub-ppm concentrations.

Replicate Analysis--

Replicate measurements are performed for ten percent of the ICPES and IC samples. This is accomplished by splitting the sample into two fractions

TABLE II-4. COMPUTER PRINTOUT FOR ICPES CALIBRATION

```
AG              CH # 1
LOW I  HIGH I     B(0)            B(1)          B(2)           B(3)
 12.36  332.6 -.7581703       .6132229E-1   .324692E-5     0

STD     CONC.        INT.     S.D.   CALC CONC.  CONC ERROR   % ERROR  CURVE
  1       0.0000    12.36     0.09      0.0001      0.0001                 1
  2       0.2000    15.60     0.27      0.1992     -0.0008      -0.38      1
  4       2.0000    44.89     0.92      2.0009      0.0009       0.05      1
  6      20.0000   332.62    12.87     19.9983     -0.0017      -0.01      1
RMS ERROR -     0.19%


AL              CH # 2
LOW I  HIGH I     B(0)            B(1)          B(2)           B(3)
 12.58  88.02 -3.240579       .2576436      .7252384E-4    0

STD     CONC.        INT.     S.D.   CALC CONC.  CONC ERROR   % ERROR  CURVE
  1       0.0000    12.58     0.18      0.0121      0.0121                 1
  3       0.2000    13.28     0.12      0.1937     -0.0063      -3.14      1
  5       2.0000    20.23     0.09      2.0004      0.0004       0.02      1
  7      20.0000    88.02     0.17     20.0000     -0.0000      -0.00      1
RMS ERROR -     1.57%


B               CH # 5
LOW I  HIGH I     B(0)            B(1)          B(2)           B(3)
  9.84  1379. -.3629143       .3592095E-1   .5421019E-6    0

STD     CONC.        INT.     S.D.   CALC CONC.  CONC ERROR   % ERROR  CURVE
  1       0.0000     9.84     0.08     -0.0093     -0.0093                 1
  3       0.5000    24.19     0.06      0.5065      0.0065       1.29      1
  5       5.1578   153.27     0.12      5.1553     -0.0025      -0.05      1
  7      50.1623  1379.00     4.61     50.2028      0.0406       0.08      1
RMS ERROR -     0.65%


BA              CH # 6
LOW I  HIGH I     B(0)            B(1)          B(2)           B(3)
 17.20  1558. -.2235907       .1296492E-1   .2537044E-7    0

STD     CONC.        INT.     S.D.   CALC CONC.  CONC ERROR   % ERROR  CURVE
  1       0.0000    17.20     0.37     -0.0005     -0.0005                 1
  3       0.2000    32.82     0.12      0.2020      0.0020       1.00      1
  5       2.0000   170.76     0.75      1.9914     -0.0086      -0.43      1
  7      20.0000  1558.27    17.92     20.0437      0.0439       0.22      1
RMS ERROR -     0.36%
```

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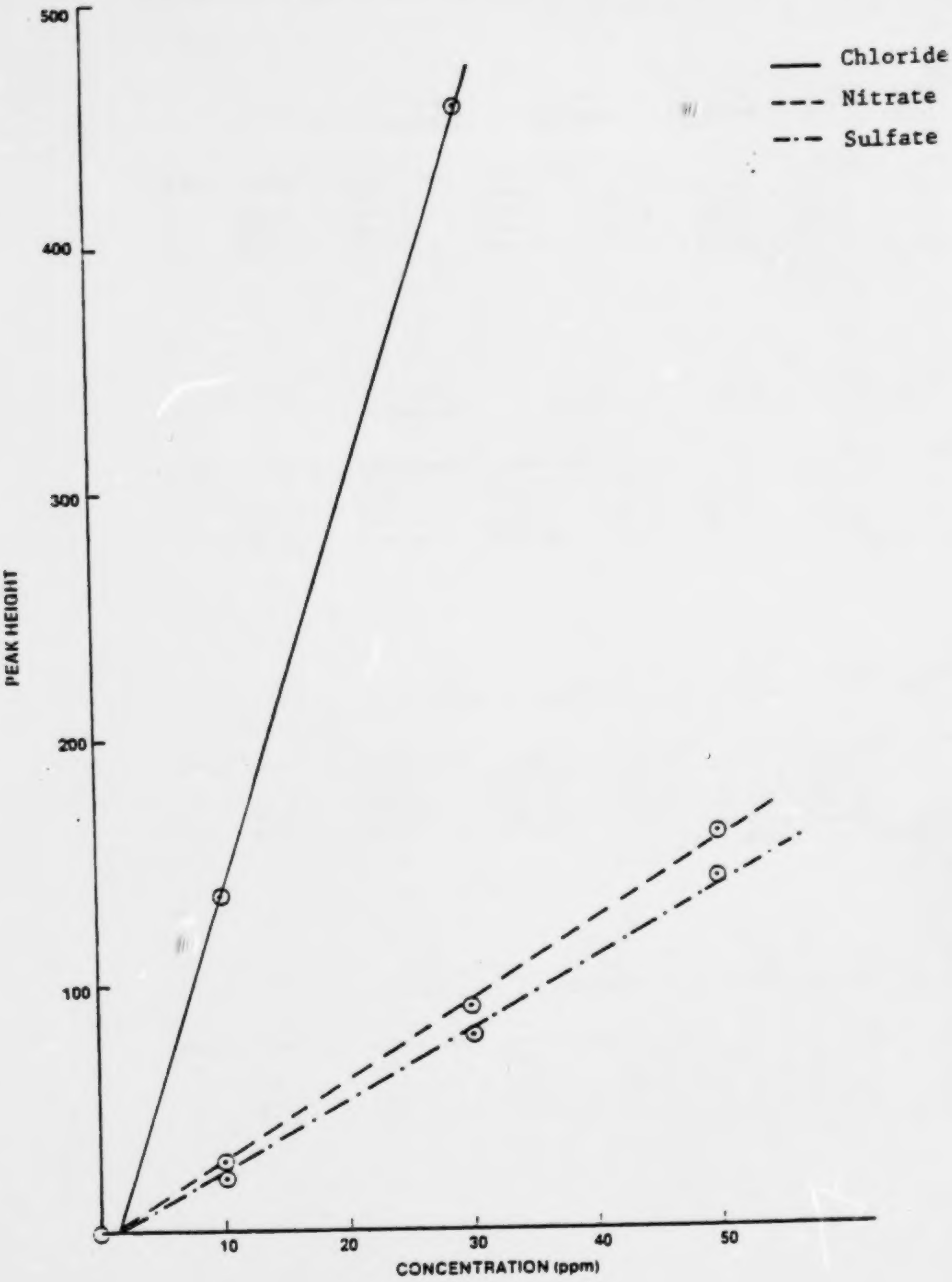

Figure II-4. IC Calibration Curve

TABLE II-5. COMPOSITION OF QUALITY-CONTROL SAMPLE FOR ICPES, IC, AND AA

Element	Concentration
Se	1
Hg	2
Li	1
Al	2
B	5
Ba	2
Ca	2
Cd	2
Co	2
Cu	2
Fe	2
K	20
Mg	2
Mn	2
Mo	2
V	2
Zn	2
Na	6
Ni	2
Si	2
Sr	2
Ti	2

with analysis of each fraction. Each ICPES analysis consists of three intergrations to provide a mean and standard deviation.

Each IC analysis for sulfate is a single determination with repeat analysis of ten percent of the samples. Total dissolved solids are analyzed with duplicate analysis of ten percent of the samples.

DETAILS OF DATA ANALYSIS PROCEDURES

The purpose of this section is to discuss the data base management and data analysis for the project. For the field cells, laboratory columns, and laboratory batch equilibration tests, data are received for inclusion in the data base in several forms. For the batch equilibration tests, data are received separately for:

- ICPES elemental analyses,
- AAS elemental analyses, and
- other chemical analyses.

For the field cells, data are received separately for:

- ICPES elemental analyses,
- AAS elemental analyses,
- other chemical analyses,
- flow-through volume, and
- rainfall.

For the laboratory columns, the same three classes of chemical analyses are performed, and the flow-through volume is measured. The laboratory columns are subjected to the same amount of "rainfall" in depth as are the field cells but at a later date (by 54 days).

Each time a set of data is received (e.g., a set of ICPES analyses for batch equilibration tests), it is stored on the computer with the necessary identifying information so that it can later be combined with the other types of information for the same batch equilibration tests. Thus, it is not necessary to wait until the data for a batch equilibration test (or field cell or laboratory column) are complete to edit or begin to analyze the data which are available.

Several partial data sets are presented here to illustrate the form of different parts of the data base. While this section is not intended to be a complete listing of raw data or a comprehensive data summary, data presentations along with interpretative discussions are presented.

In the following subsections, discussions of the software system being used for data base management and statistical analysis, the field cell data base, and the laboratory batch equilibration test data base are presented.

SAS System

The data management and statistical analysis are being performed by using the SAS software system[14], which is being accessed through a time-share computer service. An IBM 370, model 168 computer and direct access disk storage are employed. SAS is very flexible and provides a wide variety of capabilities, so that its use greatly facilitates the efficient provision for the project's software needs. Data base management capabilities include the following:

- setting up data files on the disk,

- accessing existing data files,

- subdividing data sets so that a selected part of the data can be analyzed.

- adding new observations to an existing data set,

- merging different data sets on the basis of one or more common variables (e.g., creating a new field cell data set with all AAS and ICPES elemental analyses combined by date, field cell number, and sample point), and

- transforming existing data to form new variables.

Data display capabilities include the following:

- printing data sets and formatted tables,
- producing scatter plots, and
- producing histograms and other types of plots.

The SAS system also includes a variety of statistical analysis capabilities, such as correlation and regression analysis, general linear model procedures, discriminant analysis, factor analysis, and variance component analysis. Additionally, the SAS system can be used to program any additional method which can be formulated in matrix terminology.

Field Cell and Laboratory Column Data Base

Table II-6 presents an example of the non-elemental data for field cells. In the column title "sample," the code is given which allows the different types of information for the same field cell, date, and sampling point to be identified. The first code given, for example, is 03-U-09-29-79.

The first two characters, 03, give the field cell number. The character "U" is the collection point (upper). The lower collection point is designated "L". The characters "FB" and "FL" indicate determinations made at the site, rather than in the laboratory, for leachate in the barrel and at the lower collection point, respectively. Conductivity and pH, but not chemical parameter concentrations, are being measured in the field. The final size number indicate the date on which the sample was collected in the field.

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TABLE II-6. EXAMPLE OF NON-ELEMENTAL ANALYSES FOR FIELD CELLS

	Sample	pH	Conductance µmhos/cm²	TDS ppm	SO_4 ppm	Cl ppm	F ppm	TOC ppm
15	03-[illegible]-79	7.48	13,000.	12,300.	6810.	—	0.36	14.
	03-[illegible]-79	7.27	3,900.	3950.	2040.	—	0.27	15.
	03-[illegible]-79	7.8	4,200.	—	—	—	—	—
	03-FL-09-29-79	7.2	3200.	—	—	—	—	—
16	03-U-10-14-79	7.36	7,100.	6920.	3750.	—	0.25	7.2
	03-L-10-14-79	7.21	4500.	5120.	2550.	—	0.45	9.3
	03-FB-10-14-79	7.8	4000.	—	—	—	—	—
	03-FL-10-14-79	6.9	3800.	—	—	—	—	—

It is possible to store missing values temporarily, as for chlorides in Table II-6, and later fill in the values when the analyses have been completed. The field cell number uniquely identifies the disposal medium and waste type (Table 8).

Table II-7 presents an example of field cell AAS analyses. The order in which the samples are listed on the coding forms does not matter, since the data can be sorted once they are entered in the computer. The same identifying code accompanies these data. Thus, the first line in Table II-6 and the twentieth line in Table II-7 correspond, since they both pertain to the upper collection point for field cell 3 for the collection data 9-29-79.

The ICPES data are received on floppy disks from the instrument, rather than in tabular form, as with the non-elemental and AAS analyses. The information on the floppy disks is transferred by mini-computer to tape, from which it is stored on the data base.

Table II-8 presents an example page from a computer printout of ICPES field cell data. The column headings are defined as follows:

- OBS - observation number. This is a computer-assigned index associated with a particular leachate sample and has significance only regarding data base manipulation. Note that each observation requires three lines in the printout.
- COLNO - field cell number.
- MONTH, DAY, YEAR - date the sample was collected in the field.
- IDNO - an analysis identification number assigned in the laboratory.
- ALMTH, ALDAY, ALYR - date the analysis was performed in the laboratory.

TABLE II-7. EXAMPLE OF AA ANALYSES FOR FIELD CELLS
(LITHIUM CONCENTRATIONS IN mg/ℓ)

Field Cell AACX	
Sample	Li
01-L-092079	.030
01-L-092979	.030
02-L-092079	.234
02-L-092979	.235
02-U-092979	1.63
03-L-092079	.061
03-L-082979	.208
05-L-092079	.087
05-L-092979	.069
06-L-092079	.930
07-L-092079	.02*
07-L-092979	.02
12-L-092079	.026
12-L-092979	.026
01-U-092079	3.19
01-U-092979	2.80
02-U-092079	2.38
03-U-092079	3.71
03-U-092979	3.50
04-L-092079	2.57
04-L-092079	2.21
04-U-092079	2.75
04-U-092979	2.21
05-U-092079	3.69
05-U-092979	3.11
06-U-092079	3.11
06-U-092979	2.75

*Value less than the detection limit. These are stored on the data base as the detection limit with a minus sign.

TABLE II-8. PARTIAL COMPUTER PRINTOUT OF ICPES FIELD DATA

STATISTICAL AN..LYSIS SYSTEM

OBS	COLNO	MONTH	DAY	YEAR	IDNO	ALMTH	ALDAY	ALYR	AG	AL	B	BA	CA	CD	CO	CR	CU
85	03	9	29	79	21	10	25	79	-0.00500	0.0947	8.5200	0.11900	319.0	-0.00500	-0.150	0.08550	-0.00500
86	04	8	4	79	7	8	16	79	0.01690	0.1300	6.4400	0.08420	532.0	-0.00500	0.223	0.11800	0.00678
87	04	8	6	79	20	8	16	79	C.01900	0.1310	11.2000	-0.00100	393.0	-0.00500	0.269	0.09910	0.01750
88	04	8	7	79	34	8	16	79	0.01110	0.0841	7.2400	0.01070	459.0	-0.00500	0.223	0.07000	0.00619
89	04	8	8	79	45	8	16	79	0.01360	0.0907	6.6200	-0.00100	459.0	-0.00500	0.224	0.07250	0.00589
90	04	8	11	79	57	8	16	79	0.01160	-0.0600	8.7400	-0.00100	446.0	-0.00500	0.220	0.06970	-0.00500
91	04	8	12	79	72	8	16	79	0.01520	0.0955	9.8300	-0.00100	419.0	-0.00500	0.267	0.06230	0.00722
92	04	8	14	79	9	8	29	79	-0.00500	0.0792	7.2600	-0.00100	437.0	-0.00500	-0.150	0.05660	-0.00500
93	04	8	16	79	24	8	29	79	-0.00500	0.0943	5.8500	-0.00100	439.0	-0.00500	-0.150	0.06650	-0.00500
94	04	8	19	79	39	8	29	79	-0.00500	0.1020	5.1400	-0.00100	437.0	-0.00500	-0.150	0.06830	-0.00500
95	04	8	24	79	54	8	29	79	-0.00500	-0.0600	5.2000	-0.00100	424.0	-0.00500	-0.150	0.06430	-0.00500
96	04	8	28	79	12	9	26	79	0.02050	0.3740	7.8600	0.21600	494.0	-0.00500	0.188	0.08000	-0.00500
97	04	9	2	79	26	9	26	79	0.04550	0.4220	7.0500	0.23900	485.0	-0.00500	0.277	0.09250	-0.00500
98	04	9	9	79	41	9	26	79	0.03710	0.3140	5.2800	0.15200	480.0	-0.00500	0.188	0.09160	-0.00500
99	04	9	20	79	9	10	25	79	-0.00500	0.1320	4.3100	0.09790	455.0	-0.00500	-0.150	0.07040	-0.00500
100	04	9	29	79	24	10	25	79	-0.00500	0.0749	3.9700	0.09110	427.0	-0.00500	-0.150	0.06530	-0.00500

OBS	FE	K	MG	MN	MO	NA	NI	SI	SR	TI	V	ZN	SAMPT
85	0.02970	1460.0	346.000	4.3300	0.4170	281.00	0.1170	40.8	0.527	0.01170	1.0400	0.05020	U
86	0.03820	-40.0	409.000	0.9230	1.4200	3020.00	0.4430	24.7	12.500	0.02280	0.5930	0.15600	L
87	0.04210	-40.0	303.000	0.4350	1.4200	1930.00	0.3220	17.2	8.790	0.02180	0.4770	0.07580	L
88	0.13000	-40.0	226.000	1.1400	1.0500	1510.00	0.2530	30.2	9.660	0.02670	0.3840	0.07160	L
89	0.03380	-40.0	229.000	0.9080	1.0800	1690.00	0.2480	33.7	9.820	0.01960	0.3930	0.06520	L
90	0.02990	-40.0	206.000	0.8400	1.1100	1490.00	0.2550	30.6	9.230	0.01760	0.3560	0.05710	L
91	0.02710	-40.0	163.000	0.3340	0.8880	988.00	0.2310	18.1	7.890	0.01800	0.3010	0.04270	L
92	0.02210	-40.0	136.000	0.5480	0.7200	-5.00	0.2080	24.9	9.030	0.00732	0.3040	0.03870	L
93	0.02140	-40.0	145.000	0.8670	0.8050	-5.00	0.2240	36.4	9.380	0.00930	0.3320	0.04760	L
94	0.02100	-40.0	150.000	1.1000	0.8400	-5.00	0.2500	43.8	9.610	0.01050	0.3500	0.04860	L
95	0.02860	-40.0	146.000	1.3200	0.7960	-5.00	0.2370	44.7	9.460	0.01110	0.3370	0.05890	L
96	0.02330	1250.0	23.100	0.6540	0.8570	116.00	0.2310	36.3	9.810	0.01780	0.4080	0.06040	L
97	0.01880	1280.0	25.900	0.4450	0.7810	84.20	0.2400	27.9	8.840	0.02100	0.4500	0.07360	L
98	0.02540	935.0	25.400	0.9270	0.8400	111.00	0.2210	39.5	9.770	0.01770	0.4510	0.11500	L
99	0.03240	710.0	259.000	0.8120	0.7490	524.00	0.2470	79.3	9.370	0.02430	0.8630	0.12700	L
100	0.02240	600.0	230.000	0.6800	0.5520	419.00	0.2280	62.1	7.920	0.01040	0.7660	0.07080	L

NOTE: Negative values indicate concentrations less than the detection limit.
The magnitude of the value is the detection limit.

- AG, AL, etc. - concentrations in (mg/ℓ) of the indicated elements.

- SAMPT - sample collection point; U indicates upper, and L indicates lower.

Thus, the observation 85, consisting of the second line in each of the two groups of printout in Table II-8, pertains to the upper collection point for field cell 3 for the data 9-29-79. Thus, these data correspond to line one in Table II-6 and line 20 in Table II-7.

Negative values are used to indicate concentrations less than the detection limit. The magnitude of the number equals the detection limit. For some purposes, such as calculations of the fractional attenuation:

$$A = \frac{C_U - C_L}{C_U}$$

where C_U and C_L are the concentrations of a particular element at the upper and lower collection points, respectively, the negative values are inappropriate. In these cases, the negatives have been replaced by half the detection limit.

Field cells 7 and 12 are control cells (with no waste) and have only one collection point, indicated by SAMPT = L.

The volumes of leachate in the upper collection point, the lower collection point, and the barrel are also keypunched and entered into the data base. The barrel volume is the total volume which flows through the cell excluding that removed at the collection points. Table II-9 presents an example first page in the printout of the volume data. The control cells 7 and 12, having only one sample collection point, have a missing value for the volume in the upper collection point. Missing values are shown by a period.

TABLE II-9. EXAMPLE OF VOLUME DATA (LITERS)

```
OBS    MONTH    DAY    YEAR    COLNO    UPPER    LOWER    BARREL

  1      8       4      79      01      0.182    0.015      0.0
  2      8       4      79      02      0.525    0.527      0.0
  3      8       4      79      03      0.530    0.065      0.0
  4      8       4      79      04      0.525    0.525     21.9
  5      8       4      79      05      0.520    0.040      0.0
  6      8       4      79      06      0.520    0.520     11.8
  7      8       4      79      07        .      0.415     13.5
  8      8       4      79      12        .      0.150      7.5
  9      8       6      79      01      0.530    0.530     17.0
 10      8       6      79      02      0.530    0.530     18.4
 11      8       6      79      03      0.530    0.038      0.0
 12      8       6      79      04      0.530    0.530     28.3
 13      8       6      79      05      0.530    0.530      2.5
 14      8       6      79      06      0.530    0.530     12.8
 15      8       6      79      07        .      0.530     16.0
 16      8       6      79      12        .      0.530      9.5
 17      8       7      79      01      0.348    0.530     17.1
 18      8       7      79      02      0.230    0.520      0.0
 19      8       7      79      03      0.530    0.050      5.0
 20      8       7      79      04      0.530    0.500      8.5
 21      8       7      79      05      0.530    0.530      7.0
 22      8       7      79      06      0.530    0.525      7.8
 23      8       7      79      07        .      0.530     12.5
 24      8       7      79      12        .      0.530      9.8
 25      8       8      79      01      0.000    0.210      2.0
 26      8       8      79      02      0.070    0.220      1.6
 27      8       8      79      03      0.000    0.032      0.0
 28      8       8      79      04      0.030    0.160      3.2
 29      8       8      79      05      0.000    0.130      2.1
 30      8       8      79      06      0.005    0.210      2.3
 31      8       8      79      07        .      0.195      1.5
 32      8       8      79      12        .      0.115      2.5
 33      8      11      79      01      0.530    0.530      9.6
 34      8      11      79      02      0.391    0.530      3.7
 35      8      11      79      03      0.530    0.188      0.4
 36      8      11      79      04      0.530    0.530      9.3
 37      8      11      79      05      0.530    0.346      9.0
 38      8      11      79      06      0.530    0.530      7.4
```

The rainfall data (in millimeters) are received on coding forms, from which they are keypunched and entered into the data base. The rainfall data, which apply to all field cells, are currently being stored in a separate file on the computer. It is possible to merge the rainfall data with the other field cell data by date. When this is done, the rainfall for a given date is merged with the other information for each of the eight field cells for the same date.

Table II-10 presents an example first page in a computer printout of the rainfall data. The rainfall is stored as depth in millimeters on each day, but this can easily be transformed to volume of rainfall into each field cell and to cumulative rainfall in any desired units. The large "rainfall" from 8-1-79 through 8-4-79 was actually initial irrigation intended to bring the field cells to their field capacities.

The data base for the laboratory columns will have the same form as does the field cell data base. The laboratory columns are subjected to the same "rainfall" in depth that the field cells experience, except the "rainfall" is added 54 days later. As for the field cells, the dates stored with the laboratory columns are the dates of sample collection.

Laboratory Batch Equilibration Test Data Base

Table II-11 presents an example of non-elemental data for the laboratory batch equilibration ("shake") tests. As with the field cells, the identifying code in the column titled "Sample" allows corresponding data from different sources to be identified. The first code listed, L571109A, has the following meaning:

- L - leachate sample (as opposed to disposal medium sample),
- 5 - protocol step number,
- 7 - leaching time in days.

TABLE II-10. EXAMPLE OF RAINFALL DATA

OBS	MONTH	DAY	YEAR	RAINMM
1	8	1	79	152.4
2	8	2	79	0.0
3	8	3	79	50.8
4	8	4	79	50.8
5	8	5	79	0.8
6	8	6	79	0.8
7	8	7	79	0.0
8	8	8	79	5.6
9	8	9	79	0.0
10	8	10	79	13.0
11	8	11	79	12.5
12	8	12	79	5.3
13	8	13	79	0.0
14	8	14	79	1.3
15	8	15	79	0.0
16	8	16	79	0.0
17	8	17	79	0.0
18	8	18	79	9.9
19	8	19	79	0.0
20	8	20	79	1.0
21	8	21	79	0.8
22	8	22	79	0.5
23	8	23	79	4.1
24	8	24	79	6.0
25	8	25	79	0.0
26	8	26	79	0.0
27	8	27	79	16.0
28	8	28	79	0.0
29	8	29	79	14.0
30	8	30	79	0.0
31	8	31	79	0.0
32	9	1	79	0.0
33	9	2	79	0.0
34	9	3	79	8.0
35	9	4	79	0.0
36	9	5	79	0.0
37	9	6	79	16.0
38	9	7	79	0.0
39	9	8	79	0.0
40	9	9	79	0.0
41	9	10	79	0.0

TABLE II-11. EXAMPLE OF NON-ELEMENTAL ANALYSES FOR LABORATORY SHAKE TESTS

Sample	pH	Conductance µmhos/cm^2	TDS ppm	SO_4 ppm	Cl --	F ppm	TOC ppm
L571109A	11.96	4100.	2620.	1060.		0.50	
B	11.85	5180.	2680.	1090.		0.46	
L572109A	12.06	4350.	2740.	1090.		0.50	
B	11.92	5900.	2780.	1130.		0.41	
L573109A	12.12	5400.	3010.	1130.		0.36	
B	12.04	7000.	2900.	1160.		0.36	
L574109A	12.16	6000.	3060.	1160.		0.35	
B	12.08	6800.	3050.	1190.		0.42	
L575109A	12.06	6350.	3410.	1110.		0.37	
B	12.12	7200.	3100.	1110.		0.34	
L576109A	12.42	5700.	3400.	1180.		0.43	
B	12.39	6500.	3450.	1240.		0.45	

- 1 - step number (protocol steps 2, 3, 5, and 6 involve successive leachings and this index allows those leachings to be put in sequence),

- 1 - code for waste type,

- 09 - code for disposal medium, and

- A - first of two or more replicate performances of a particular shake test. In Table II-9, the replicate pairs are listed together.

All laboratory analyses completed so far are for waste type 1, which is Exxon PFBC waste. Table II-12 presents the codes for the disposal media.

The data handling for the AAS and ICPES elemental analyses is exactly as discussed above for the field cells. The AAS data are received in tabular form, keypunched, and entered into the data base. The ICPES data are received on floppy disks, transferred to tape, and then entered into the data base. ICPES and AAS analyses are made for the same elements for the laboratory data as for the field cell data. The same laboratory protocol identifying codes (e.g., L571109A, discussed above) are used for all three kinds of chemical analysis, so that the different analyses for the same shake test can be identified. This procedure is analogous to that used for the field cells, which is discussed in detail in the preceding subsection.

TABLE II-11. CODES FOR DISPOSAL MEDIA FOR LABORATORY SHAKE TESTS

Code	Attenuating Medium
08	Shale
09	Interburden
10	Sandstone
11	Greer Limestone
12	Glacial Till
13	Alluvium
14	Limestone